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MISSION TO THE RSUP PULAU BURUNG COCONUT PLANTATION (SUMATRA / INDONESIA)
3rd November to 14th December 1997

Research on the factors limiting the yields of the PB121 hybrid coconut variety

R. PHILIPPE (Entomologist) & **C. JOURDAN** (Root Physiologist)

CP SIC 914 bis March 1998

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CONTENTS

MISSION SCHEDULE

Monday 3rd November 1997 :	Left Montpellier 6:40 am Left Paris 11:10 am	
Tuesday 4th November 1997 :	Arrived Singapore 7:30 am, left for Batam 8:45 am Arrived Batam 9:15 am, left for RSUP 10:30 am Arrived at plantation 12:30 pm, met by Messrs Lilik, Husni	
Wednesday 5th November 1997 :	Met Mr Sam Pak Lam (Plantation Manager) Visited all the experimental plots	
Thursday 6th November 1997 :	Choice of site and palms for rhizotron installation in A07-02	
	R. PHILIPPE	Update of all the data acquired from July to October 1997 and planning of activities
	C. JOURDAN	Installation of vertical rhizotrons
Friday 7th November 1997 :	R. PHILIPPE	Root sampling in seed garden of plot A
	C. JOURDAN	Continued installation of vertical rhizotrons
Saturday 8th November 1997 :	R. PHILIPPE	Root sampling in seed garden of plot K1-02
	C. JOURDAN	Completion of vertical rhizotron installation and start on installing horizontal rhizotrons
Sunday 9th November 1997 :	Rest and data processing	
Monday 10th to Friday 14th :	R. PHILIPPE	Sampling and measurements in plots A07-01 November 1997 and A07-02
	C. JOURDAN	Completion of horizontal rhizotron installation, installation of piezometer network, start on major digging
Saturday 15th November 1997 :	Meeting with Messrs Lilik, Husni and Rachmat	
Monday 17th November 1997 :	R. PHILIPPE	Root sampling in seed garden of plot K1-03
	C. JOURDAN	Further major digging in A07-02.
Tuesday 18th November 1997 :	R. PHILIPPE & C. JOURDAN Tour of trial RS ES 07 and other plots at RSTM	
Wednesday 19th November 1997 :	R. PHILIPPE	Root sampling in seed garden of plot K1-03
	C. JOURDAN	Major digging in A07-02 (cont.), sampling for histological analysis in plot K03-01
Thursday 20th November 1997 :	R. PHILIPPE	Tour of coconut nursery
	C. JOURDAN	Major digging (completion) and palm felling in A07-02
Friday 21st November 1997 :	R. PHILIPPE	Root sampling in seed garden of plot K1-05 Light trapping trial
	C. JOURDAN	Palm felling and root counts

Saturday 22nd November 1997 :	R. PHILIPPE Measuring distance between palms in A07-02 C. JOURDAN Root counts (cont.)
Sunday 23rd November 1997 :	Rest and data processing
Monday 24th November 1997 :	R. PHILIPPE Insecticide treatment in A07-01 and 07-02 Sampling in plot 10-02 C. JOURDAN Visit of BRS (oil palm)
Tuesday 25th November 1997 :	R. PHILIPPE *Sufetula* rearing trial on artificial medium Preparation of healthy roots and drying C. JOURDAN Visit of BRS (oil palm)
Wednesday 26th November 1997 :	R. PHILIPPE & C. JOURDAN RSTM trial RS CC 21: felling 6-month-old palms Observations of RSUP oil palms
Thursday 27th November 1997 :	Meeting with RSUP Management Installation of clear plastic sheets on rhizotrons
Friday 28th November 1997 :	R. PHILIPPE Sampling in plot K1-02 Completion of insecticide treatments C. JOURDAN Left for Singapore, then France
Saturday 29th November 1997 :	Sampling in plots K1-03, 04 Root counts on felled palms (completion)
Sunday 30th November 1997 :	Rest - writing up mission report
Monday 1st December 1997 :	Sampling in plot K2-01 Labelling new trial HSF 14 in plot A07-01 Installation of plastic sheets on rhizotrons (cont.) and felling of four new coconut palms
Tuesday 2nd December 1997 :	Sampling in plot 08 - 16 A Labelling new trial HSF 14 in A07-01 (cont.) Start on installing nut husks around coconut palms Felling of four new coconut palms (cont.)
Wednesday 3rd December 1997 :	Labelling new trial HSF 14 in A07-01 (completion) Felling of four new coconut palms (completion).
Thursday 4th December 1997 :	Installation of nut husks around coconut palms (cont.) Root counts on felled palms
Friday 5th December 1997 :	Installation of nut husks around coconut palms (cont.) Root counts on felled palms (cont.)

Saturday 6th December 1997 :	Installation of nut husks around coconut palms (cont.) Collection of 28 bags of cocopeat from KM 00 and spreading in afternoon Root counts on felled palms (completion)
Sunday 7th December 1997 :	Rest - writing up mission report
Monday 8th December 1997 :	Examination of rhizotrons Start of trial in A07-02 and continuation of trial in A07-01 Collection of *Sufetula* larvae
Tuesday 9th December 1997 :	Continuation of trial in A07-01 Collection of *Sufetula* larvae (cont.)
Wednesday 10th December 1997 :	Collection of *Sufetula* larvae (cont.) Continuation of trial in A07-01 Collection of adult Pyralidae in trial RS ES 21 for determination
Thursday 11th December 1997 :	Collection of *Sufetula* larvae (cont.) Continuation of trial in A07-01 Afternoon meeting with RSUP Management
Friday 12th December 1997 :	Collection of *Sufetula* larvae and preparation Continuation of trial in A07-01
Saturday 13th December 1997 :	Left for Singapore
Sunday 14th December 1997 :	Left for France

ACKNOWLEDGEMENTS

The authors would like to thank all the members of RSUP Management at the plantation, particularly Messrs Sam Pak Lam and Lilik Qusairi, all the senior staff - Messrs Husni, Rachmat and Kairudin - and all those in the Crop Protection and Agronomy Services, for their warm welcome, for giving up their time and for their willingness to cooperate, which facilitated the smooth running of the mission.

We should also like to thank those in charge at the BRS plantation, particularly Messrs Sahid Martono and Chew, the agronomists - Messrs Rislianto and Syahbuddin - and their staff for their welcome, help, and for providing us with plant material.

SUMMARY

This joint mission by an entomologist and a physiologist specialized in the study of root systems, undertaken in November and December 1997, confirmed that attacks by *Sufetula* caterpillars are partly responsible for the low coconut yields at RSUP in Pulau Burung. Indeed, large excavations around the foot of high-yielding and poor-yielding 10-year-old palms revealed limited lengthwise growth of the roots: 1 to 3 m, rarely more, as opposed to 7 to 9 m for palms of the same age under non-limiting conditions. The root elongation rate seems to be very slow. The number of primary roots is abnormally high, by successive reiterations. Moreover, it is surprising to see the existence of a dry zone stretching for a radius of 80 cm around the stem and up to 30 cm deep, whereas the water table is only 1 m down. It is precisely in that dry zone that most of the tertiary and quaternary roots, the most absorbent roots in the system, are found. Lastly, the dry zone has been observed just beneath the stem, down to a depth of 80 cm in some palms, within the plot. There is also severe soil erosion, following heavy rainfall, in a radius of 2 m around the stem. The erosion is combined with natural compaction of the peat, all of which goes to form a characteristic mound around the base of the coconut palms. This leads to exposure of mostly absorbent roots near the surface, which then dry out in the sun and are consequently more vulnerable to caterpillar attacks.

Be that as it may, the caterpillars of this species are most probably not responsible for the substantial heterogeneity seen in coconut palm growth; it is mainly induced by other factors, such as the level of the water table. The heterogeneity is seen in the existence of very tall palms (over 7 m tall), medium-sized palms (5 to 6 m) and smaller palms (2 to 3 m). All three of these categories are attacked to varying degrees by the caterpillars, which partly prevents a correlation being established between the caterpillar attack rates and the number of nuts. However, it was possible to show a good triangular relation between coconut palm height, the fresh weight of their roots and the number of nuts borne by the palms.

Moreover, it is apparently difficult to establish a good relation between the caterpillar attacks and coconut yields, as the cumulated effect of the attacks cannot be accurately measured; indeed, the attacks are not severe, are sudden and are limited in time and space. They are rather slight in general and occur on a continuous basis over the months and years but at different places. The generations overlap.

Sufetula has a 38-day development cycle. The larva cycle takes place entirely in the ground; pupation occurs either on the inside or outside of the roots. It is therefore very hard to reach the caterpillars directly by insecticide treatments, thereby making it very difficult to precisely assess the true biological effectiveness of toxic molecules. Two trials have shown that three insecticides can be used against this insect: Larvin (Thiodicarb), Dursban (Chlorpyrifos) and Supracide (Methidathion). Monthly treatments are not totally satisfactory for preventing attacks by these caterpillars; it will be necessary to use an adhesive to reduce leaching by heavy rainfall. Six months after the insecticide treatments, the beneficial effect of treatment on yields, if any, is still not clear.

A new trial has been set up to control *Sufetula*, to improve the degree of moisture near the soil surface and to reduce erosion: covering the soil up to 2 m around the stem with coconut husks, with or without insecticide treatment - covering of the soil up to 2 m around the stem with "cocopeat" (husk fibre residues) with or without insecticide treatment - insecticide treatment alone - control without circle weeding.

INTRODUCTION

In 1990, the coconut palms on the RSUP coconut estate at Pulau Burung started showing the following typical symptoms to varying degrees:

- Dry bunches without nuts, sometimes many of them: up to 5 or 6 dry bunches in succession,
- Premature drying out of lower leaves.

These symptoms were seen more or less everywhere at this plantation, spreading to varying degrees depending on the place. At the same time as these observations, coconut yields were also found to be stagnating, at levels that were clearly below the potential yields of the PB 121 hybrid, throughout the commercial plantings. Five hypotheses were therefore put forward to try and explain the low yields of the planting material under the ecological conditions at RSUP:

- Effect of planting density
- Effect of water table height
- Effect of land preparation
- Effect of mineral nutrition
- Effect of *Sufetula* caterpillar attacks on the root system.

All the hypotheses have been studied over the last ten years; some of them are still being investigated in trials under way at the moment.

Trial RS CC 04 showed that a **density of 180 plants/ha does not induce dry bunch and/or prematurely dry lower leaf symptoms** (Desmier de Chenon & Bonneau, mission report Doc CP 678 - November 96).

The existence of dry bunch and/or prematurely dry lower leaf symptoms is independent of the water table gradient; this was seen both in the plots or parts of plots with a relatively high water table, and in those with a relatively low water table. This excludes plots in the bottomlands which are often flooded, where the coconut palms suffer and show typical asphyxia symptoms on waterlogged soil. We can state that, out of the variations observed, it is unlikely that yield stagnation is due to the water table height (Desmier de Chenon & Bonneau, mission report Doc CP 678 - November 96).

Moreover, it is unlikely that yield stagnation is due to land preparation. Indeed, good land preparation undoubtedly induces uniform coconut palm growth (as at RSTM), hence earlier yields, but yield also stagnates once a plateau is reached (Desmier de Chenon & Bonneau, mission report Doc-CP 678 - November 96).

In addition, the hypothesis of a silica deficiency seems to be increasingly unlikely. It is also unlikely that another deficiency is responsible for yield stagnation (Desmier de Chenon & Bonneau, mission report Doc CP 678 - November 96).

During the June 1997 mission (Philippe, mission report DOC CP SIC 846, September 97), coconut palm growth was seen to be highly heterogeneous throughout the plantation. Caterpillar attacks were as numerous along the edges of drains as inside the plots. However, along such drains, the first two or three rows of coconut palms are mostly very good yielders.
The high-yielding palms (more than 100 nuts on the palm) are just as severely attacked as the low yielders (fewer than 70 nuts).
The root systems of coconut palms planted on clayey soils are also considerably attacked by these caterpillars, despite the compacted soil. On average, though, those coconut palms produce very good yields, like any conventional PB 121, and their vertical growth is virtually uniform.
A lack of water availability in the first five centimetres of soil could be substantially disrupting the functioning of the tertiary and quaternary roots which are very dense at that level and may also be causing low yields. Other agronomic factors must have caused stress when the palms were young, for such irregular coconut palm growth to have occurred.
In addition, statistical analyses of the observations recorded during the June 97 mission only revealed partial correlations, thereby suggesting the possible interference of another limiting factor (or factors) and/or the cumulative effect of attacks by the caterpillars, which is obviously very difficult to assess with any accuracy.

Consequently, it was proposed that a joint mission by an entomologist and a physiologist specializing in root studies be carried out in November and December 1997.

EFFECT OF *Sufetula* (Lepidoptera - Pyralidae) ATTACKS ON COCONUT PALM YIELDS AT RSUP

(R. PHILIPPE)

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I. *Sufetula* BIOLOGY

The insect's biology was studied at the RSUP plant protection laboratory in large Petri dishes (personal communication by Husni of results obtained with Desmier de Chenon).

Egg incubation		4 to 5 days (average = 5 days)
Larva development, 5 instars		16 to 22 days (average = 19 days)
Pupation		3 to 9 days (average = 6 days)
Pre-oviposition period		5 to 11 days (average = 8 days)
Total biological cycle	=	**28 to 47 days (average = 38 days)**

Samples of *Pyralidae* adults were collected and brought back to Montpellier for determination; the insects collected from the ferns in the plot revealed the existence of two or three *Pyralidae* species. *Sufetula sunidesalis* was among the adults emerging from the pupae obtained from caterpillars taken from coconut roots, but there were also other, lighter-coloured adults, with just one black spot on each of the upper wings and fewer dark patches and broken whitish lines than on *S. sunidesalis* wings.

II. STUDY OF *Sufetula* POPULATION DYNAMICS

II.1. Method

Samples were taken every month from December 1996 onwards, from 40x40x40 cm holes 1.5 m from the stem, along the coconut planting row, to the South or the North. Ten palms were taken at random in nine 6 to 10-year-old plots. The new attacks rate was calculated as follows: number of new attacks over the total of healthy roots, roots with old attacks and newly attacked roots.

II.2. Results

Figures 1 to 9 show that the recent attacks, which can be recognized through the existence of more or less oxidized dejecta, or the presence of caterpillars in the galleries, were not very numerous in most of the plots observed; the attack rate was 7% of recently attacked roots on average, with a maximum of 13% and a minimum of 2.5%. Recent attacks fluctuated during the year in the nine observation plots.

A09-08	March 90 (Figure 2)	very small proportion of newly
B09-04	August 87 (Figure 5)	attacked roots throughout
B11-09	July 88 (Figure 6)	the entire year

A10-07	March 90 (Figure 4)	a peak in March (more than 20% freshly attacked roots)

Figure 1 : Sufetula population dynamics in B09-16

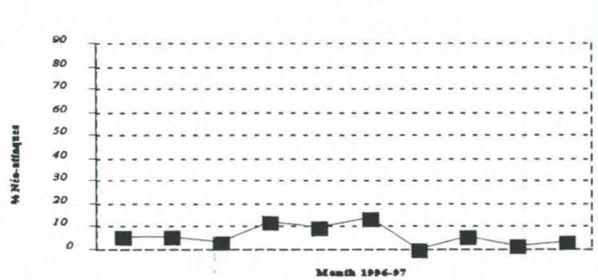


Figure 2 : Sufetula population dynamics in A09-08

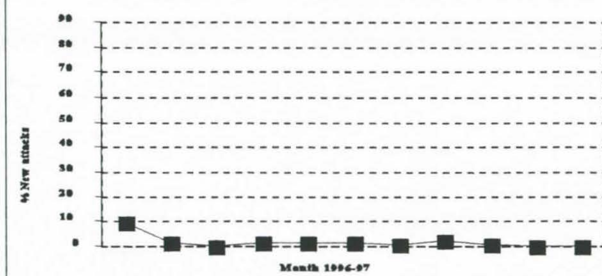


Figure 3 : Sufetula population dynamics in A06—03

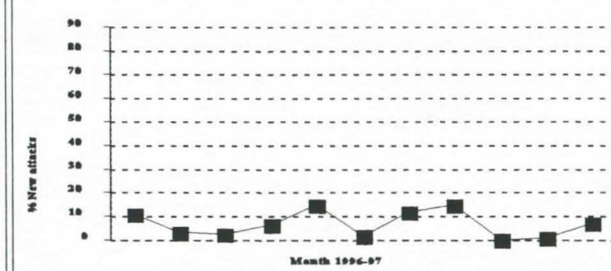


Figure 4 : Sufetula population dynamics in A10-07

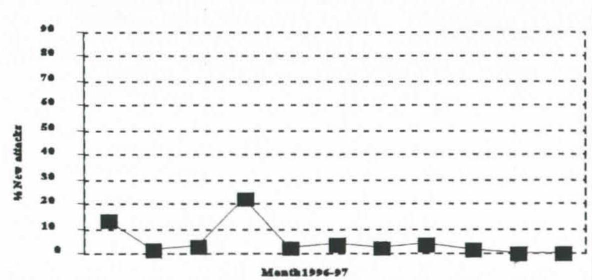


Figure 5 : Sufetula population dynamics in B09-04

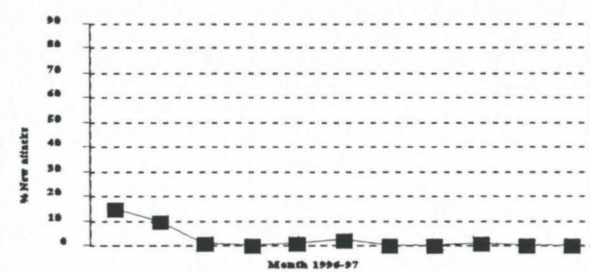


Figure 6 : Sufetula population dynamics in B11-09

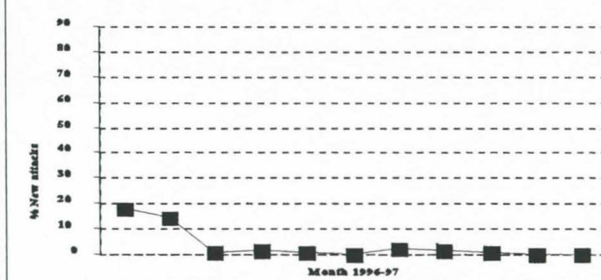


Figure 7 : Sufetula population dynamics in K03-01

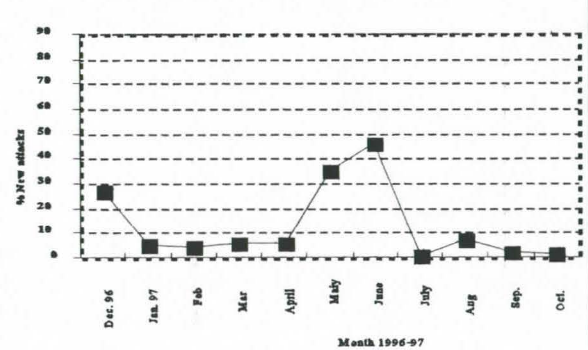


Figure 8 : Sufetula population dynamics in A12-03

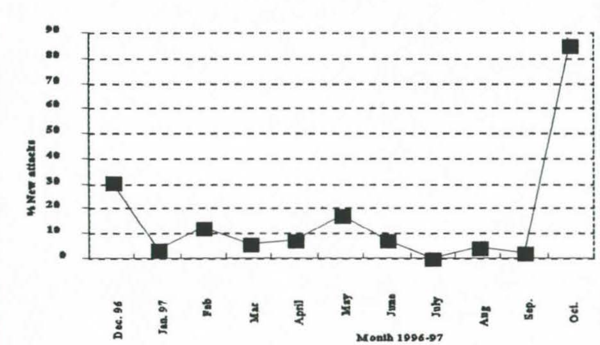
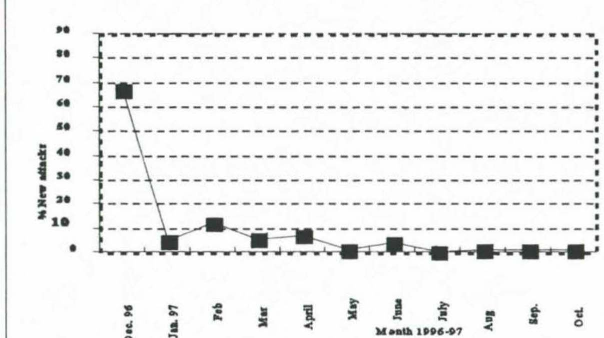


Figure 9 : Sufetula population dynamics in A10-05



B09-16	May 90 (Figure 1)	increase in new attacks from March to May 97
A06-03	June 87 (Figure 3)	a peak in April and two others in June and July 97
A10-05	Sept. 87 (Figure 9)	severe new attacks in December 96, then a gradual decrease in attacks since that date
K03-01	April 87 (Figure 7)	new attacks of moderate intensity in December 96, then a further increase in May and June 97
A12-03	May 89 (Figure 8)	new attacks of moderate intensity as in K03-01 in December 96, then a fluctuation in attacks under 20%, followed by a sudden increase in new attacks in October 97.

For 1998, we recommended keeping five plots: A06-03 ; A09-08 ; B11-09 ; K03-01 and A12-03, to monitor *Sufetula* population dynamics. Root samples will be taken from two 1.00 m x 0.40 m x 0.40 m holes, one in the coconut planting row and the other perpendicular to the axis of the planting row in the interrow, 0.80 m from the stem. It will also be interesting only to totalize the number of healthy roots and the number of newly attacked roots.

III. ANALYSIS OF *Sufetula* ADULT EMERGENCE UNDER NATURAL CONDITIONS - HSF 9

Alongside trial HSF 05, another similar test, HSF 09 / A06-03 / RSUP, was set up on 18th June 1997 with transparent plastic sheets forming a 6 m x 7 m rectangle. Three palms (C1 to C3) have already been prepared in that way. No insecticide treatment was carried out. Every week, the plastic sheets were removed from round the three palms to collect and count all the *Sufetula* adults found, then the sheets were put back in place. In August 97, three new coconut palms (C8 to C10) were added.

Figure 10 shows that weekly adult emergence was very low on average. It was also irregular from one palm to another and one week to the next (figures 11 to 20). That suggests that the generations overlap.

IV. LIGHT TRAPS - HSF 13

Two trapping sessions were held from 7:00 pm onwards using a mercury-vapour lamp: one in the plot located just behind the laboratory (connected to the mains) and the second in trial plot RS CC 21 (using a small electricity generating set). No *Sufetula* adults were attracted by the light. It should also be pointed out that very few insects (dragonflies, small green grasshoppers, leafhoppers, etc.) came towards the light, which was surprising. That suggests that the insect life in the plant cover is not particularly substantial.

In a future mission, it will be interesting to test an actinic tube which emits near ultra violet rays and a blacklightorWoodtube, which emits long U.V. waves.

Figure 10 : Analysis of Sufetula adult emergence in K06-03

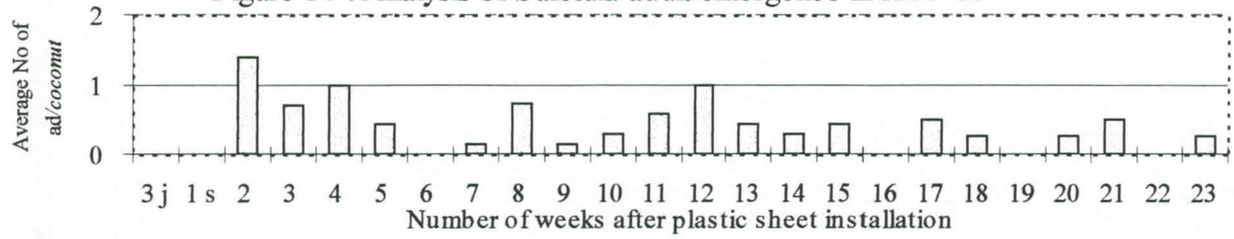


Figure 11 : Sufetula adult emrgence on coconut palm C1

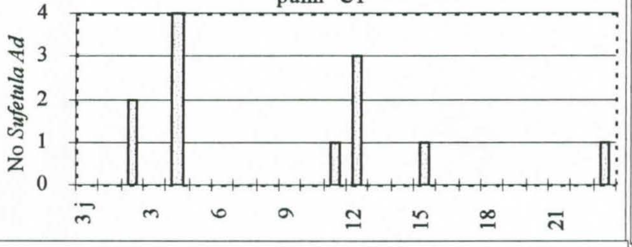


Figure 12 : Sufetula adult emrgence on coconut palm C2

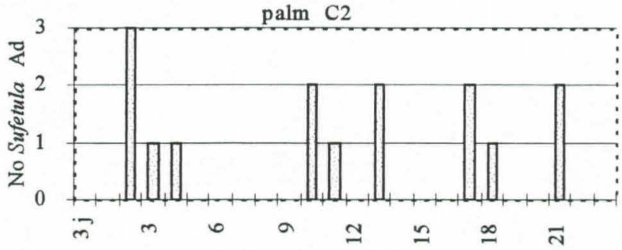


Figure 13 : Sufetula adult emrgence on coconut palm C3

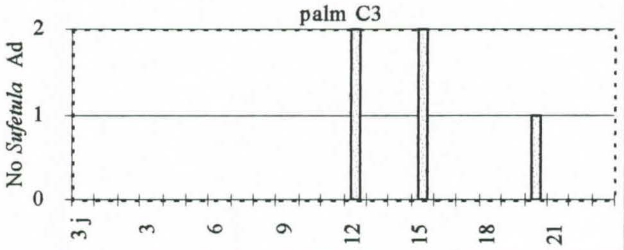


Figure 14 : Sufetula adult emrgence on coconut palm C4

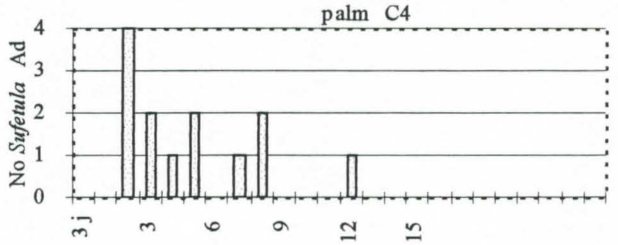


Figure 15 : Sufetula adult emrgence on coconut palm C5

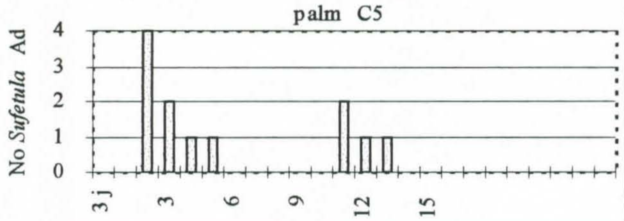


Figure 16 : Sufetula adult emrgence on coconut palm C6

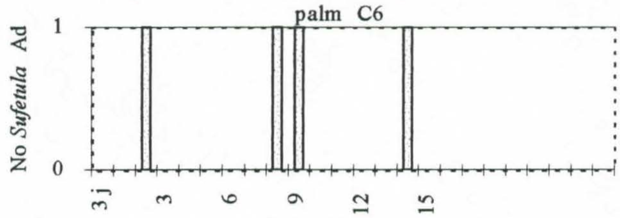


Figure 17 : Sufetula adult emrgence on coconut palm C7

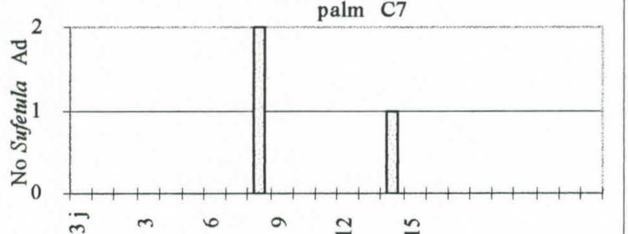


Figure 18 : Sufetula adult emrgence on coconut palm C8

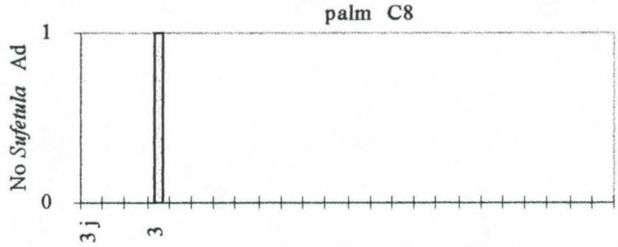


Figure 19 : Sufetula adult emrgence on coconut palm C9

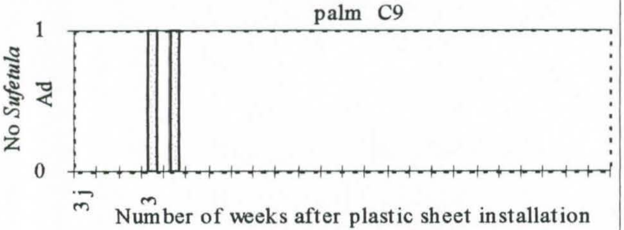
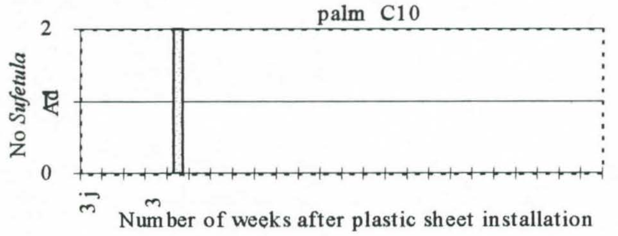


Figure 20 : Sufetula adult emrgence on coconut palm C10



V. *Sufetula* REARING -HSF 12

It is possible to get adults to lay eggs by placing them in a large Petri dish with around a centimetre of peat. The eggs hatch well; the first instar larvae quickly move to the bottom of the dish. They are then given primary roots and new roots are added every week, but it will be difficult to obtain mass rearing in that way.

Trials bringing different instar larvae into contact with a synthetic medium composed of wheat and corn flours revealed that if they were closed in a cavity first, two old larvae out of the six tested mined a gallery. The small larvae drowned in this medium as it contained too much water, but if the medium is too dry it soon goes hard. Samples of dry primary, secondary and tertiary roots were brought back to Montpellier to obtain a dry powder for use in making up a new test medium.

VI. SEARCH FOR A PHEROMONE IN *Sufetula* FEMALES

Two hundred and eighty-nine larvae in the final two or three instars were collected from roots and germinated nuts in the plantation over a five-day period with two to four collectors working each day. The larvae were brought back to Montpellier in root fragments. Forty-five pupae and 57 adults were obtained from the sample, i.e. 102 individuals in all, which were sent to the Chemical Mediators Laboratory in Versailles (France), in two batches as their emergence was staggered in time. P. Zagatti, a specialist at the laboratory, only recovered 13 living females from the adults, as all the pupae were killed by the cold; the adults seem to have resisted better in transit. Chromatography analyses will be carried out at a later date.

A second sample of caterpillars will be brought back to Montpellier by Xavier Bonneau at the beginning of March 98.
He will give them to P. Zagatti who will be able to collect the emerging adults directly.

VII. RELATION BETWEEN *Sufetula* ATTACKS ON ROOTS AND YIELDS

This time, root samples were taken from three 40x40x40 cm holes, oriented in three directions: North, Southeast and Southwest, 80 cm from the stem, in plots A07-01 and A07-02.

As during the previous mission in June 1997, it is also difficult to establish a significant correlation between the caterpillar attack rates on any category of roots and the number of nuts or female flowers present on the different coconut leaf ranks (Tables 1 & 2). This confirms the fact that heterogeneity, caused by other agronomic factors, clearly masks the correlation. Moreover, the lack of correlation could also mean that the current condition of the root system results from an accumulation of attacks, of varying intensity, over months and years.
It should be remembered that attacks by these caterpillars can begin very early, right from planting. Indeed, *Sufetula* attacks can already be found on the roots of germinated nuts in bearing plantings.

Table 1: Matrix of the coefficients of correlation between the number of nuts and the percentage of healthy roots in plot A07-01

Roots	R1	R2	R3	R1+R2+R3
Number of nuts or flowers	%Healthy	%H	%H	%H
L10	0.041	-0.257	-0.093	-0.184
L11 to L13	0.045	-0.252	-0.042	-0.141
L14	-0.172	-0.144	0.170	-0.024
L15 to lowest L	-0.127	-0.248	0.026	-0.127
Total flowers + nuts	0.015	-0.270	0.005	-0.145

Table 2: Matrix of the coefficients of correlation between the number of nuts and the percentage of healthy roots in plot A07-02

Roots	R1	R2	R3	R1+R2+R3
Number of nuts or flowers	%Healthy	%H	%H	%H
L10	-0.153	-0.051	0.258	0.080
L11 to L13	-0.234	-0.294	0.159	0.008
L14	-0.229	-0.048	0.021	-0.197
L15 to lowest L	-0.402	-0.344	-0.095	-0.269
Total flowers + nuts	-0.377	-0.322	0.015	-0.187

VIII. ANALYSIS OF *Sufetula* ATTACK DISTRIBUTION DEPENDING ON THE COCONUT VARIETIES AND HYBRIDS

VIII.1. Plot A (Seed garden No. 1)

For each of the five coconut palms sampled per plant or variety, the roots were taken from three 40x40x40 cm holes oriented in three directions: North, Southeast and Southwest, 80 cm from the stem.

This plot contains the CRD and NYD varieties, along with oil palm.
The overall attack rate on all the roots observed was around 20% (Table 3). In these deep peats, *Sufetula* attacks are found on the subterranean roots of the oil palms.

Table 3: Distribution of *Sufetula* attacks on oil palm and on two coconut varieties

CROP	R1	R1	R2	R2	R3	R3	TOTAL	%TOTAL
	Total	%attacks	Total	%attacks	Total	%attacks	ROOTS	ATTACKS
Oil palm, July 1990	94*	22.34	366	24.04	1454	25.24	1914	24.87
Coconut								
NYD, August 1989	158	47.47	215	38.14	946	21.56	1319	27.37
CRD, September 1989	127	31.50	143	32.87	707	25.32	977	27.23

* = total number of roots (R1, R2 and R3) found in the three holes for the five palms of each plant or variety

VIII.2. Plots K1-02, 03, 04, 05

These plots, which represent the RSUP collection, have been planted with different varieties: Rennell (RLT - Solomon Islands: 5.7 ha; West African Tall (WAT): 8.3 ha; Igo Duku (Indonesia): 5.1 ha; Polynesia Tall (PYT): 3.8 ha; Concong Tall (Indonesia): 3.7 ha; Bali Tall (Indonesia): 2.5 ha; Khima Tall (Indonesia): 2,5 ha; Tenga Tall (Indonesia): 2.5 ha; Palu Tall (Indonesia): 2.5 ha; Guntung Tall (Indonesia): 2.5 ha; Takome Tall (Indonesia): 2 ha; Ta Tall (Indonesia): 4.8 ha; Dau Tall (Vietnam): 4.6 ha; Eo Tall (Vietnam): 1.5 ha; Xiem Tall (Vietnam); Nyass Yellow Dwarf (Indonesia): 2.3 ha; Cameroon Red Dwarf (CRD): 2 ha; Salak Tall (Indonesia): 2 ha; Raja Tall (Indonesia): 2 ha; Malayan Yellow Dwarf (MYD): 2 ha; Ternate Tall (Indonesia): 2 ha; Malayan Red Dwarf (MRD): 4.1 ha.

For each of the five coconut palms sampled per variety, roots were taken from a 80x40x40 cm hole oriented perpendicular to the axis of the planting row, in the interrow 80 cm from the stem. For the West African Tall and Igo Duku varieties, roots were taken from three 40x40x40 cm holes and oriented in three directions: North, Southeast and Southwest, 80 cm from the stem.

Table 4 shows that all the varieties are attacked by *Sufetula* to varying degrees. Nevertheless, it can be seen that four varieties: the Indonesian Concong, Khima, Tenga and Palu talls, had a very low overall attack percentage (10 to 20%) compared to the other varieties, as they had a considerable quantity of tertiary roots with few signs of attack (around 10%); on the other hand, their primary and secondary roots were just as attacked, if not more so, as the other varieties. In addition, the Malayan Yellow Dwarf shows signs of moderate attacks (around 30%) on the three categories of roots compared to the other varieties, which had severe attacks on the primary and secondary roots. It will therefore be worth monitoring *Sufetula* attacks every six months on the MYD to compare it with the PB 121 and a few other varieties such as BALI and XIEM.

Table 4: Distribution of *Sufetula* attacks depending on the coconut varieties in the seed garden (plots K1-02, 03, 04, 05)

VARIETIES	PLANTING DATES	R1 total	R1 %attacks	R2 total	R2 %attacks	R3 total	R3 %attacks	TOTAL ROOTS	%TOTAL ATTACKS
WAT	Nov-89	370*	60.54	290	66.55	1071	54.44	1731	57.77
IGO DUKU	Sep-89	456	54.17	523	57.17	8921	56.28	9900	56.23
RLT	Sep-89	187	79.68	151	68.87	831	46.57	1169	54.75
CRD	Sep-89	40	45.00	119	42.02	1013	34.95	1172	36.01
PB 121	1989	169	72.78	300	55.33	2451	27.34	2920	32.84
Bali	Jun-90	379	94.99	300	69.33	1353	37.40	2032	52.85
PYT	Jun-90	465	87.53	373	73.99	1050	58.10	1888	68.49
CONCONG	Jun-90	261	89.66	178	60.11	9886	15.12	10325	17.78
KHIMA	Jun-90	393	86.01	394	75.63	14172	9.36	14959	13.12
TENGA	Jun-90	123	82.11	248	54.44	11619	9.10	11990	10.76
PALU	Jun-90	266	75.94	483	56.31	21345	6.48	22094	8.64
SALAK	Oct-90	39	46.15	181	50.83	1122	44.12	1342	45.08
RAJA	Oct-90	38	60.53	58	43.10	629	31.64	725	34.07
MYD	Oct-90	27	29.63	76	36.84	1107	31.07	1210	31.40
PB 121	1990	235	85.53	178	61.80	2604	24.54	3017	31.40
GUNTUNG	Aug-91	201	77.61	220	59.55	21054	26.67	21475	27.48
MRD	Aug-91	29	62.07	31	58.06	491	36.66	551	39.20
PB 121	1991	99	80.81	96	64.58	1090	25.96	1285	33.07
NYD	Oct-92	59	62.71	136	46.32	1547	24.69	1742	27.67
PB 121	1992	227	66.52	189	50.26	4105	14.13	4521	18.27
TERNATE	May-93	39	51.28	60	38.33	586	26.28	685	28.76
PB 121	1993	168	80.95	146	71.23	3918	24.66	4232	28.50
DAU	May-94	59	66.10	53	50.94	2114	53.69	2226	53.96
XIEM	May-94	52	34.62	140	60.00	2192	45.03	2384	45.68
TAKOME	Apr-94	56	53.57	111	59.46	3231	42.84	3398	43.56
EO	May-94	50	46.00	126	43.65	2004	41.62	2180	41.83
TA	May-94	39	53.85	69	34.78	1530	25.03	1638	26.13
PB 121	1994	127	55.91	129	51.94	3882	21.35	4138	23.37

* = total number of roots (R1, R2 and/or R3) found in the holes for the five palms of each variety

VIII.3. Plot K02-01

This is a genetic trial set up in October 1989 (4.8 ha) with three hybrids: Khina 1 (NYD x Palu); PB 111 (CRD x WAT); PB 121, the reference hybrid.

For each of the five coconut palms sampled per variety, roots were taken from an 80x40x40 cm hole oriented perpendicular to the planting row, in the interrow 80 cm from the stem.

All three hybrids were severely attacked by *Sufetula* (Table 5).

Table 5: Distribution of *Sufetula* attacks depending on the coconut varieties in plot K02-01 (genetic trial)

VARIETIES	R1 total	R1 %attacks	R2 total	R2 %attacks	R3 total	R3 %attacks	TOTAL ROOTS	%TOTAL ATTACKS
KHINA 1	211	82.94	139	74.82	1806	72.20	2156	**73.42**
PB 111	217	86.64	181	78.45	1548	61.11	1946	**65.57**
PB 121	162	83.33	152	68.42	1522	64.26	1836	**66.29**

* = total number of roots (R1, R2 and R3) found in the holes for the five palms of each hybrid

VIII.4. Plot A08-16

This plot is planted with the PB 113 hybrid = CRD x RLT.

For each of the five coconut palms sampled, roots were taken from four 80x40x40 cm holes: two holes to the North and South of the planting row and two others to the West and East, perpendicular to the planting row, in the interrow 80 cm from the stem.

This hybrid is also severely infested (Table 6).

Table 6: Distribution of *Sufetula* attacks on the PB 113 hybrid in plot A08-16

VARIETIES	R1 total	R1 %attacks	R2 total	R2 %attacks	R3 total	R3 %attacks	TOTAL ROOTS	%TOTAL ATTACKS
PB 113	389	84.32	279	70.97	5252	51.49	5920	**54.56**

* = total number of roots (R1, R2 and R3) found in the four holes for the five palms

IX. PRELIMINARY INSECTICIDE RESULTS

IX.1. Insecticide tests: HSF 10 / A07-01 / RSUP

IX.1.1. Purpose

The purpose is to find a more effective and especially more persistent insecticide than Dursban. No records of insecticide trials in the past were found at RSUP. Dursban was considered to be effective against *Sufetula* and very high doses were used successively, then gradually decreased.

IX.1.2. Material and method

Every month (D1) and every two weeks (D2), 15 ml of Dursban 20EC (chlorpyrifos, organophosphorous), the reference product, were applied with 6 litres of water per coconut palm, in a radius of 2 m around the palms. This insecticide is effective against underground pests. Its persistence in the soil is around three months. It is broken down in the soil by hydrolysis and microbial action.

The following three insecticides were also applied in the same way every month:

- Dimacide, dimethoate-based (396 g/litre of commercial product): the tested dose was 10 ml/6 litres of water/coconut palm (DM). It has systemic properties and acts by contact and ingestion on numerous insects. It has good persistence: 2 to 3 weeks.

- Supracide (SU), methidathion-based, organophosphorous (420 g/litre of commercial product): the tested dose was 10 ml/6 litres of water/coconut palm. It acts by contact and ingestion and has a certain action at depth on a large number of insects. Multi-purpose with a persistence of 2 to 3 weeks.

- Larvin (L), thiodicarb, carbamate-based (375 g/litre of commercial product): the tested dose was 6 ml/6 litres of water/coconut palm. It acts by contact and ingestion on a large number of insects. It also has penetrating properties enabling it to pass through insect egg walls and kill them.

Treatments were started on 26th June 1997. The trial is due to last six months. Root samples were taken in June 1997 from the central coconut palms of each elementary plot (five rows x five palms - Figure 21): 1 hole/coconut palm 0.80 m from the stem. In September 1997, samples were still taken from one hole/coconut palm 0.80 m from the stem, but from two coconut palms per elementary plot. However, in November 1997, samples were also taken from two other different coconut palms in each elementary plot, but from three holes per coconut palm: one to the North in the planting row, one to the Southwest and one to the Southeast towards the interrows, 0.80 m from the stem.

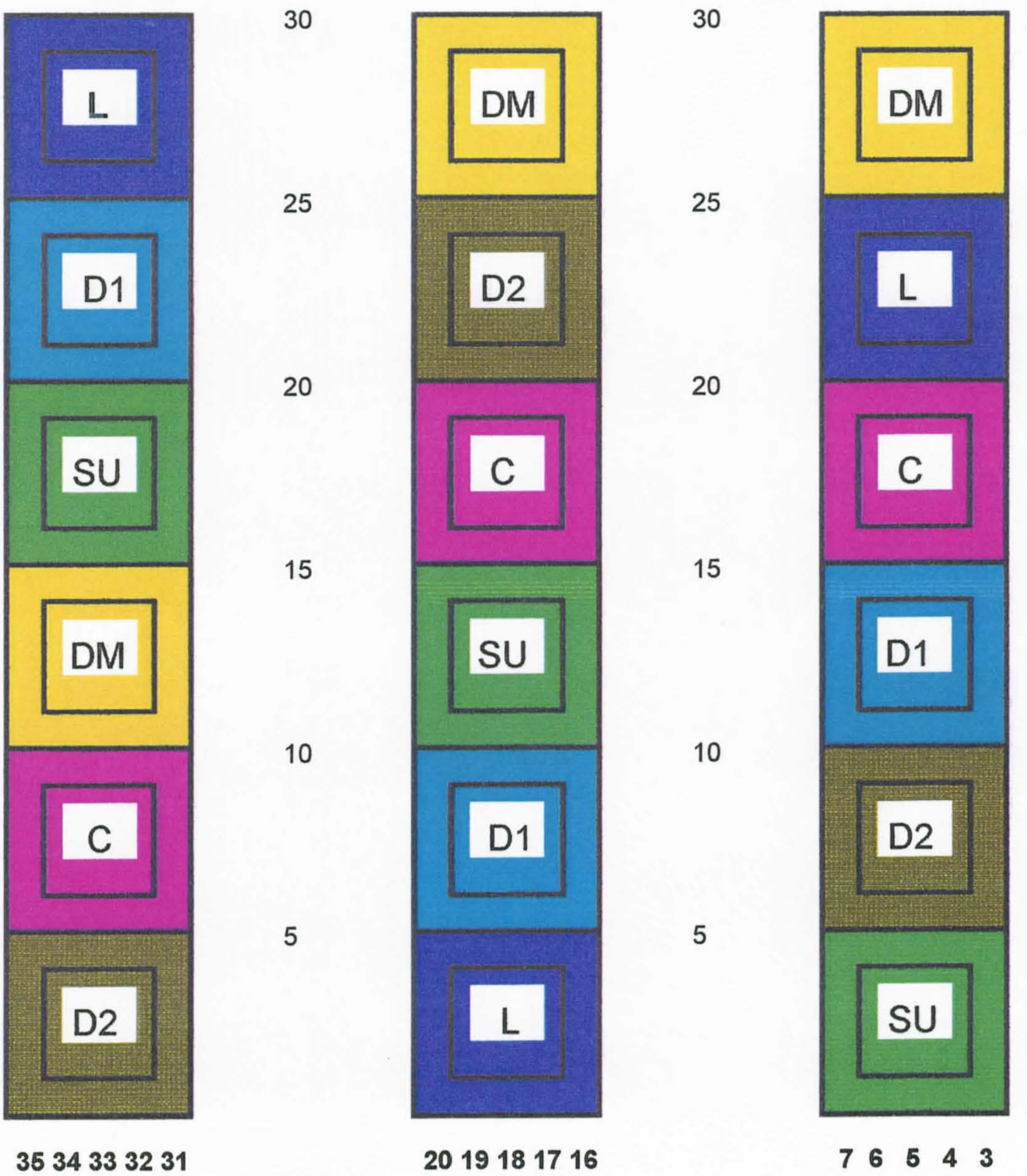
"Old attacks" was the term used to describe all the fragments of sampled primary roots that showed reiterations after total destruction of the previous apexes.

"New or recent attacks" was used to describe all the fragments of sampled roots that revealed apexes with the existence of galleries containing living larvae or more or less oxidized caterpillar excreta. In this case there was no sign of reiteration following the attack.

Figure 21 : A 07- 01 - HSF 10 - RSUP

TRIAL OF THREE INSECTICIDES

D1	15 ml Dursban / 6 litres of water / palm	Every month
L2	12 ml Larvin / 6 litres of water / palm	Every month
L	6 ml Larvin / 6 litres of water / palm	Every month
SU2	20 ml Supracide / 6 litres of water / palm	Every month
SU	10 ml Supracide / 6 litres of water / palm	Every month
C	Control without cleaning circle around palms	



"Healthy roots" describes all the fragments of sampled roots that revealed healthy apexes, irrespective of reiteration length.

An initial nut count was made on 21/06/97 on all nine central palms of each elementary plot (mission report DOC CP SIC 846, September 97). The subsequent counts were made every three months on the same nine central palms in all the elementary plots.

IX.1.3. Results

Table 7 shows that twice-monthly treatments with Dursban proved more effective than the monthly treatments, but unfortunately it will be impossible to generalize them. Dimacide was not at all effective against these miner caterpillars. However, Larvin seemed to protect the root system well from attacks by this insect, and better than chlorpyrifos and Supracide.

Nevertheless, none of these insecticides totally prevented attacks by the caterpillars. That suggests that the insecticides are leached away too quickly by successive heavy rains. Root development varies considerably depending on the coconut palms. Fresh *Sufetula* attacks were also very rare in the control.

It would therefore be wise to incorporate an adhesive in the insecticide solution (1 ml per litre of solution).

IX.1.4. Comments

In view of the results, we made changes by replacing two of the treatments (D2 = Dursban every two weeks and DM = Dimacide) in this trial to test doses of Larvin (L) and Supracide (SU).
L2, to replace D2, 12 ml of Larvin/6 litres of water/coconut palm every month
SU2, to replace DM, 20 ml of Supracide/6 litres of water/coconut palms every month
The other treatments (D1 Dursban, L Larvin, SU Supracide, every month, Control) remain unchanged (Figure 21).

Table 7: Results after six months of an insecticide trial - HSF 10 / A07-01

Insecticide	Percentage of new attacks (%)		
	June 97	September 97	November 97
Dursban 15 ml every month	0.7 (47)	2.8 (107)	2.5 (94)
Dursban 15 ml every 2 weeks	5.8 (75)	0.7 (143)	1.34 (149)
Dimacide 10 ml every month	6.35 (42)	1.86 (134)	17 (78)
Supracide 10 ml every month	2.6 (38)	1.26 (145)	4.3 (72)
Larvin 6 ml every month	1.05 (32)	4.64 (83)	1.04 (59)
Control	2.3 (87)	3.6 (145)	3.45 (143)

0.7 = (Total new attacks on R1+R2+R3 /Total healthy R1+R2+R3 roots) x 100(47) = Average number of healthy roots per hole

IX. 2. Effect of *Sufetula* attacks on yields: HSF 11 / A07-02 / RSUP

IX.2.1. Purpose and reminder

We are attempting to show that frequent chemical treatments at high doses can lead to an effective and significant increase in yields through recovery of a healthy root system.

An initial trial, RS ES 56, was set up on 3rd August 1992. After two years, an undoubted tendency was seen towards a positive Dursban effect on the number of green leaves and on fruit-set (Bonneau, internal report 1994), but it has not been possible to confirm it, particularly as the visible effect in the field has been disappointing. It has therefore not been possible to conclude on any depressive *Sufetula* effect.

IX.2.2. Material and method

Every month or every two weeks, 30 ml of Dursban 20EC, the reference product, are applied with 6 litres of solution in a 2-m radius around each coconut palm in the elementary plots (5 rows x 5 palms - Figure 22). The treatments were begun on 29th June 1997. The trial is to last at least 24 months.

The arrangements relative to root sampling and nut counting defined in the previous trial also apply to this one.

IX.2.3. Results

Table 8 shows that the treatments with a dose of 30 ml of Dursban per coconut palm give the same results when carried out every month as they do when carried out every two weeks. In this case, the high Dursban doses seem to effectively check *Sufetula* attacks. However, as in the previous plot, A07-01, attacks by this insect are also very rare in A07-02; this is the result of a very low *Sufetula* population in the previous months.

It can also be seen for this plot that root development is highly variable from one coconut palm to another, with the control palms having more healthy roots on average, which will make it very difficult to accurately assess the effect of *Sufetula* on yields, as we suspected during our previous mission.

Table 8: Results after 6 months of insecticide treatments against *Sufetula* to improve yields - HSF 10 / A07-01

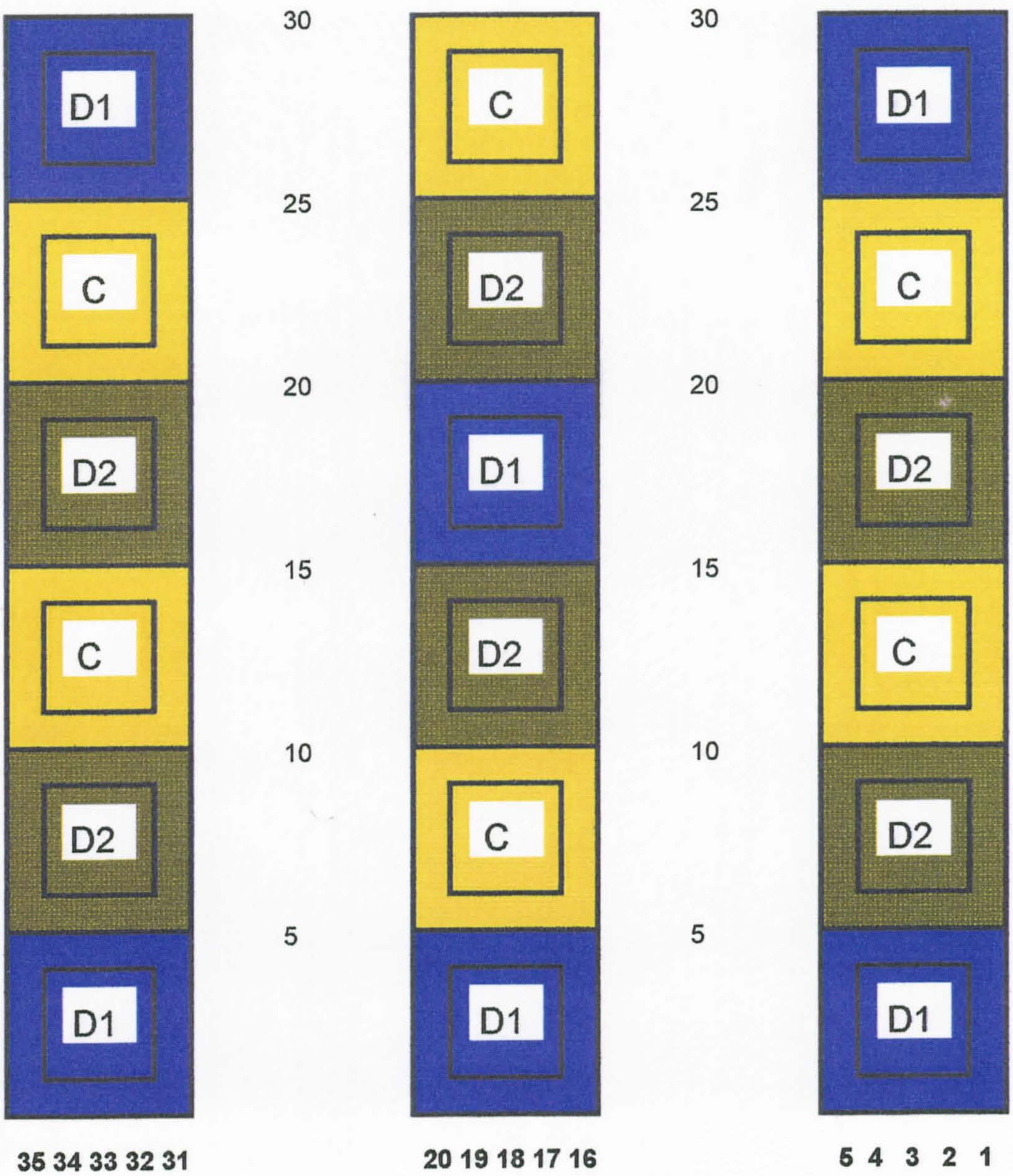
Insecticides	Percentage of New Attacks (%)		
	June 97	**September 97**	**November 97**
Dursban, 30 ml every month	1.6 (93)	0 (101)	0.5 (294)
Dursban 30 ml every 2 weeks	1.4 (83)	0 (105)	0.5 (290)
Control	1.9 (31)	0.34 (143)	1.27 (327)

1.6 = (Total new attacks on R1+R2+R3 / Total healthy R1+R2+R3 roots) x 100
(93) = Average number of healthy roots per hole

Figure 22 : A 07- 02 - HSF 11 - RSUP

STUDY OF THE EFFECT OF *Sufetula sunidesalis* ON THE PRODUCTION

D1	**30 ml Dursban / 6 litres of water / palm**	**Every month**
D2	**30 ml Dursban / 3 litres of water / palm**	**Every month**
C	**Control without treatment nor cleaning the circle around the palms**	



IX.2.4. Comments

In view of the results, we made changes by replacing treatment D2 (= Dursban every 2 weeks) in this trial to test the spraying volume: 3 litres of solution instead of 6 litres applied every month in a 2-m radius around each coconut palm. The other treatments (D1 Dursban, every month, Control) remain unchanged.

Shortly before the end of the trial, major excavations will be carried out to analyse in detail the root systems of the coconut palms protected from *Sufetula* attacks.

Nut counts were carried out on the coconut palms before treatment, then every three months; for the time being, no difference can be seen between the treated palms and the control. Starting in January 1999, ripe nuts will be collected to assess the true yields of the different treatments.

X. ANALYSIS OF THE PRELIMINARY RESULTS OF TRIALS HSF 05 AND 07

X.1. HSF 05

X.1.1. Purpose

The purpose was to find out whether stronger protection against *Sufetula* leads to significant and sustainable regeneration of the root system, hence to a reduction in DBL symptoms (prematurely dry bunches and lower leaves), in other words to an increase in the number of green leaves and the bunch load.

X.1.2. Reminder of the protocol

This trial, which is located in plot A06-03/RSUP (where *Sufetula* pressure is very high) compares two groups of coconut palms: 11 untreated controls and 11 palms protected from *Sufetula* attacks.
Protection consists in laying a plastic sheet in a radius of 2 m around the stem, to prevent the butterflies from laying their eggs. In addition, Dursban applications at standard doses and concentrations have been sprayed under the sheets every month or every fortnight since June 1997 (Desmier de Chenon and Bonneau, DOC. CP 678/96, p.9).

The trial was launched in December 1996; the 11 treated palms with plastic sheets are in a continuous group of 5 palms in the same planting row and 6 in a neighbouring row. The same applies for the 11 control palms.

X.1.3. Results

Before and after treatment, the bunches at leaf 10 were marked on all the palms chosen for the trial; the bunches were then monitored during the following month. Table 9 gives the percentages of fruits remaining in the bunch once the identified leaves have reached rank 14 (i.e. three months after marking), then rank 19 (i.e. six months after marking).

Only a very slight difference can be seen between the treated palms and the controls 4 months after treatment, at leaf 14 and leaf 19: **+ 2 to 3%** fruits remaining in the bunches of the palms protected from *Sufetula*. However, the difference in favour of the treated palms is no longer seen 5 and 6 months after treatment.

However, the coconut palms with protection (plastic sheet and treatment) against *Sufetula* have a larger number of healthy roots than the controls whose circles were merely weeded (Table 10).

X.1.4 Comments

The initial opaque plastic sheets, which had been torn, were replaced by transparent plastic.

Table 9 : Trial HSF 05 - Protection with plastic sheets and treatment against *Sufetula*

Period	**Percentage of fruits remaining in bunches marked at L10 once they reach at L14 or L19**	
	L14 (3 months after marking)	**L19 (6 months after marking)**
Before treatment		
Treated	**16.87%**	**16.97%**
Control	**22.83%**	**15.75%**
3 months after		
Treated	**27.39%**	**14.01%**
Control	**34.29%**	**22.14%**
4 months after		
Treated	**24.86%**	**20.90%**
Control	**22.03%**	**17.51%**
5 months after		
Treated	**35.56%**	
Control	**45.27%**	
6 months after		
Treated	**33.73%**	
Control	**35.93%**	

Table 10 : Trial HSF 05 - Protection with plastic sheet and treatment against *Sufetula*
10 months after, checked 1.5 m from the stem - Mean for 11 palms

TYPE	R1			R2			R3			Total new attacks	Total attacked roots	Total healthy roots
	H	ex-At	new-At	H	ex-At	new-At	H	ex-At	new-At			
Control	3.1	12.9	9	7.2	12.6	0.3	67.7	164.9	0.5	**9.8**	**190.4**	**78**
Treated	14.3	11.3	0.5	17	8.9	0	207	53.8	0.8	**1.3**	**74**	**237.8**

H = Healthy; ex-At = old attacks; new-At = new attacks

X.2. HSF 07

X.2.1. Purpose

Reproduction of bunch and leaf desiccation symptoms by root sectioning.

X.2.2. Reminder of the protocol

This trial was set up in plot A07-05/RSUP, in accordance with the report on the visit by Desmier de Chenon and Bonneau (DOC. CP 678/96, p.9).
Ten uniform-looking, not necessarily adjacent coconut palms were chosen, on which six treatments were applied:

- A = control without root sectioning
- B = 25% sectioned roots (on twice 1/8 of a circle)
- C = 50% sectioned roots (on four times 1/8 of a circle)
- D = 75% sectioned roots (on 3/4 of a circle)
- E = 100% sectioned roots (on complete circle)
- F = cutting points scattered within the circle

The trenches were dug 1 m from the stem, to a depth of 1 m and refreshed every month. They were widened to the width of a spade to make them more visible, except in treatment E, where the coconut palms were found to become unstable if the trench was widened.
The trial comprises 4 blocks and 24 elementary plots (4 x 6). It was begun in December 1996; however, as trench digging was long and delicate work, it was only completed in March 1997. *Sufetula* caterpillars are controlled as well as possible by applying Dursban on the surface in the circle, at a frequency of twice a month, given that the trial is only of any interest if *Sufetula* does not interfere with it.

X.2.3. Preliminary results

Table 11 shows that after 7 months of observations following the sectioning of 100% of the roots around each of the chosen coconut palms, there was only a difference of around 8% in nut fall compared to the control.

It is also important to point out that, according to the trials carried out by C. JOURDAN in Vanuatu, primary and secondary root iterations are only possible if the cut is near the apex, and *Sufetula* penetrates the roots by entering primarily at the apex. The root sectioning carried out in the trial did not often occur near the apex, since it was done 1 m from the stem.

Moreover, in this trial, there will not be any clear and decisive answer as regards the additional artificial stress inflicted upon the coconut palms; it has to be borne in mind that they have already been under stress for many years due to *Sufetula* and other agronomic factors. In addition, the reaction to all these past events varies substantially from one coconut palm to another. This type of trial will have to be conducted on coconut palms with as healthy as possible a root system, right from a young age, which may be possible in two or three years' time in the neutral rows of trial RS CC 07 at RSTM.

So, this trial does not precisely simulate the effect of *Sufetula* caterpillars. Consequently, we advised halting it as soon as possible.

Table 11: Trial HSF 07 - Reproduction of nut fall and dry leaf symptoms by root sectioning

Treatments	Percentage nut fall		
	1 month after root sectioning		7 months after root sectioning
	L14	L19	L14
Control A	67.22	72.70	76.23
25% sectioned roots B	70.24	73.64	74.83
50% sectioned roots C	66.49	68.69	75.26
75% sectioned roots D	61.68	64.56	80.18
100% sectioned roots E	70.51	76.68	84.91
Scattered root sectioning F	62.97	68.30	78.51

OTHER AGRONOMIC FACTORS AFFECTING COCONUT YIELDS AT RSUP

OTHER AGRONOMIC FACTORS AFFECTING COCONUT YIELDS AT RSUP

I. RELATION BETWEEN PALM HEIGHT, WEIGHT OF ROOTS AND YIELDS

At the time of the previous coconut root sampling operations in three holes: 1 to the North on the planting row, 1 to the Southeast and 1 to the Southwest in the interrows, each root sample was weighed after washing with water and rapidly draining; the height was measured from the ground to the base of leaf 14 and the nuts present on the coconut palm were totalized per leaf level.

The data were subjected to correlation calculations; the variations were considerable, as the height measurements could be not be carried out precisely and the roots were weighed to the nearest 20 g on a Roberval balance, so there were obviously numerous inaccuracies. The averages were therefore considered for the height categories, the weights of fresh roots and the number of nuts + flowers on the palms.

It was thus possible to obtain good links between the three parameters (Tables 1 and 2):

- The taller the palms the more nuts + flowers (total palm load) were found
- The higher the fresh weight of the roots, the taller the coconut palms
- The higher the fresh weight of the roots, the more nuts + flowers were found.

Table 1 : Matrix of the coefficients of correlation between fresh root weights, palm height and the number of nuts + flowers in plot A07-01

	Fresh weight of roots	
Height	+ 0.893	**Height**
Number of nuts+flowers	+ 0.796	+ 0.910

Table 2 : Matrix of the coefficients of correlation between fresh root weights, palm height and the number of nuts + flowers in plot A07-02

	Fresh weight of roots	
Height	+ 0.424	**Height**
Number of nuts+flowers	+ 0.508	+ 0.963

These results clearly show the existence of considerable heterogeneity in the planting, which results from the stress suffered by the coconut palms early after planting, as we suspected during our previous mission. The stress may be due to excess water from poor drainage, which can result in poorer land preparation. **This explains why a trial with young coconut palms is required.**

It is therefore now very easy to understand the problems encountered in obtaining good correlations between the percentage of caterpillar attacks and the number of nuts on the coconut palms. The palms that were tall, hence high yielders in general (more than 100 nuts), were just as severely attacked as the smaller palms which were, in general, low yielders.

II. ANALYSIS OF TRIAL RS CC 07 / PLOT 02-04 / RSTM

The purpose is to demonstrate the role of silica and *Sufetula* attacks on coconut yields. It was set up on 26th May 1997. Preventative insecticide treatments have been carried out with Dursban every two weeks, so far.

During two tours of this 6-month-old plot, we saw that the treatments were carried out well in compliance with the established standards. We also saw quarterly felling of the coconut palms in the double density rows. No *Sufetula* attacks have yet been detected. The absence of attacks is attributable to a zero *Sufetula* population, which results from elimination of the plant cover prior to planting (virtually bare soil).

However, plant growth was found to be highly heterogeneous (Photos 1 & 2): the plants located in the dips were not growing well at all and were smaller than the others, which were placed at random on mounds. The water table was around twenty centimetres below the surface due to poor drain upkeep, but the problem has now been solved.
We mapped two rows in this plot (10th and 20th rows) categorizing the plants according to size (from spear tip to ground):

- Tall plant	=	around 2.00 m
- Medium plant	=	around 1.25 m
- Small plant	=	around 0.70 m

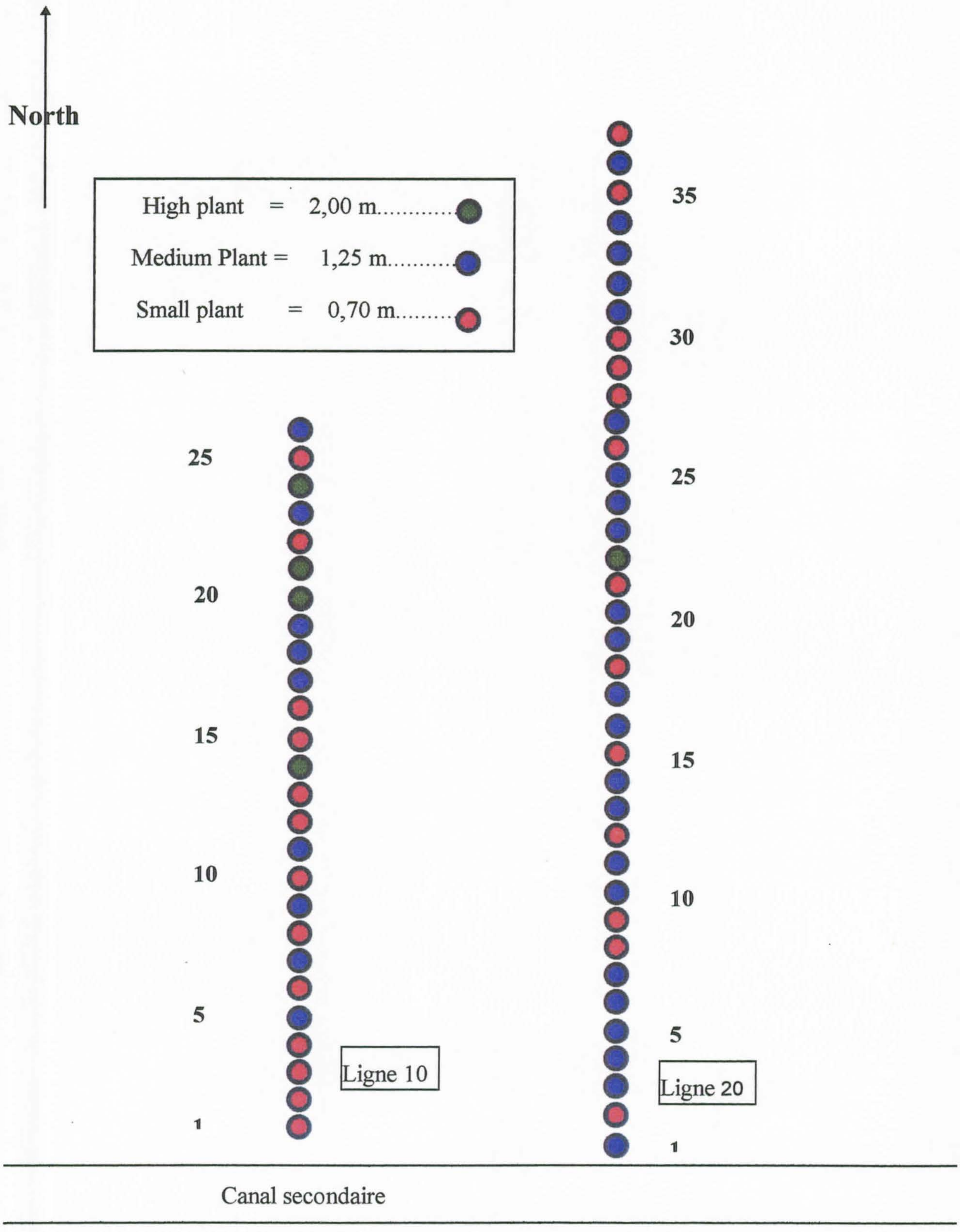
Figure 23 shows the existence of considerable heterogeneity in the development of 6-month-old plants and the trauma may have an effect in future on production potential (to be confirmed in a few years), since it is now known that small PB 121 coconut palms are usually poor yielders. The distribution of the three size categories among the 6-month-old plants in the two rows is virtually the same as that for the three categories of nut yielders (10-year-old coconut palms) in plots A07-01 and A07-02 (Fig. 4 to 7, CPSIC 846 - September 1997).
For the time being, there are no *Sufetula* attacks, so the insect is not responsible for the early heterogeneity of the plants in this plot.

Consequently, this plot is useful in more ways than one, since it will be used as the control for monitoring a plot of the same age, planted at RSTM under normal conditions with a more or less dense cover crop that already shows signs of *Sufetula* attacks. It would therefore be worth studying the spread of ferns in this plot, which harbour three Microlepidoptera, and the emergence of a *Sufetula* population.

Photo 1 & 2 : RS CC 07 / RSTM 2-04 - NOVEMBRE 1997 : ESSAI ENGRAIS SILICEUX ET CONTRÔLE DE *SUFETULA* - HÉTÉROGÉNÉITÉ DES PLANTS DE 6 MOIS, DUE À UNE HAUTEUR TROP ÉLEVÉE DE LA NAPPE D'EAU.

Photo 1 & 2 : RS CC 07 / RSTM 2-04 - NOVEMBER 1997: TEST OF SILICON FERTILIZER AND *SUFETULA* CONTROL - HETEROGENEITY OF 6 MONTHS OLD PLANTS DUE TO A HIGH WATER TABLE.

Figure 23 : Mapping of the 6 months old plants height in the plot 02-04 / RS CC 07 / RSTM planted on May 1997



In addition, given the absence of *Sufetula* attacks due to the current zero population, we recommended monthly treatments instead of the fortnightly ones. Once the first attacks are seen on the control plants, a return to fortnightly treatments will be necessary with twice the dose currently used.

III. EROSION AND MOUNDING

In the plots of coconut palms aged at least 10 years, substantial erosion was seen at the base of the palms plumb with hanging leaves and bunches, i.e. between 50 cm and 1.5 m from the stem (photo 3). The erosion is mainly caused by rainwater runoff channelled along the leaves, from the base of the leaves and from the bunches. The situation is amplified by the very structure of the soil, as the surface of the peat is severely degraded and consists of very fine, very light particles giving it a dusty appearance with maximum porosity.

The result of the process is to uncover the primarily absorbent surface roots, which dry out in the sun (Photo 4).

The erosion is combined with subsidence or natural compaction of the peat, resulting in a characteristic mound at the base of the coconut palms (Photos 5 & 6). Peat subsidence can reach 30 cm in places despite the compaction carried out during land preparation at the time of planting. The mounds vary in size with a maximum height of 30 cm in the study plot, A 07-02, aged 10 years at the time of the observations. Due to the form of the mounds, which are sometimes quite steep, in the worst cases the roots can be uncovered for up to a metre from the stem (Photo 4 and 5) or they are near the surface and therefore vulnerable to attacks by *Sufetula* caterpillars.

Localized erosion and mound formation at the base of the coconut palms will have to be rectified rapidly at the RSUP plantation, if root functioning problems, root biomass loss and increased *Sufetula* attacks are to be avoided.

IV. NURSERY

No *Sufetula* attacks have been seen on the roots of nursery plants. Germination seems to be heterogeneous from one seed bed to another. The root systems do not seem to be very homogeneous from one plant to the next either. Out of 17 4-month-old nursery plants with four leaves, two had fewer than five primary roots and very poor development; three had a very good root system with 15 to 20 primary roots and a good root mat; the other 12 plants had a moderately developed root system: 5 to 10 primary roots with a very variable root mat. Under poor environmental conditions: water table too high, poor land preparation, the plants with a very good root system could resist and probably give very good yields (more than 100 nuts/coconut palm/year); however, the plants with a moderate root system are likely to give adults with poor yields (fewer than 70 nuts/coconut palm/year) or sometimes average production (between 70 and 100 nuts/coconut palm/year).

It would therefore be worth closely studying nut germination and plant development on peat: girth, leaf dimensions, to effectively define criteria for culling in the nursery.

In fact, if culling is carried out properly, after six months there should be plants with around 25 R1 and a root mat filling the entire volume of the polybag.

V. COCONUT PALM SPACING

The planting design in 8-m equilateral triangles has been adopted at RSUP, but a few measurements of the distances between the coconut palms in the same planting row or from one row to the next in the South of plot A07-02: rows 31 to 35, 15 to 21 and 1 to 5, revealed that the coconut palms were rarely 8 m apart along the planting rows (minimum = 6.10 m; maximum = 10.45 m). In addition, the distance between the planting rows was not always 7 m (photos 7 & 8). These irregularities result from the existence of tree trunks which were not windrowed and which got in the way when the coconut palms were planted; this situation would seem to cause competition for light, which could be harmful over time. Two agronomy trials have been set up to study these particular aspects (RS CC 04 and RS ES 57).

Photo 3 : EFFET DE L'EROSION AU PIED D'UN COCOTIER.
Photo 3: EFFECT OF EROSION BY THE FOOT OF A COCONUT.

Photo 4 : MISE À NU DES RACINES SUPERFICIELLES.
Photo 4 : EXHIBITION OF SUPERFICIAL ROOTS.

Photo 5 & 6 : EFFET DE L'EROSION AU PIED D'UN COCOTIER - FORMATION D'UNE BUTTE ET MISE À NU DES RACINES SUPERFICIELLES.
Photo 5 & 6 : EFFECT OF EROSION BY THE FOOT OF A COCONUT - .FORMATION OF A HILLOCK AND EXHIBITION OF SUPERFICIAL ROOTS.

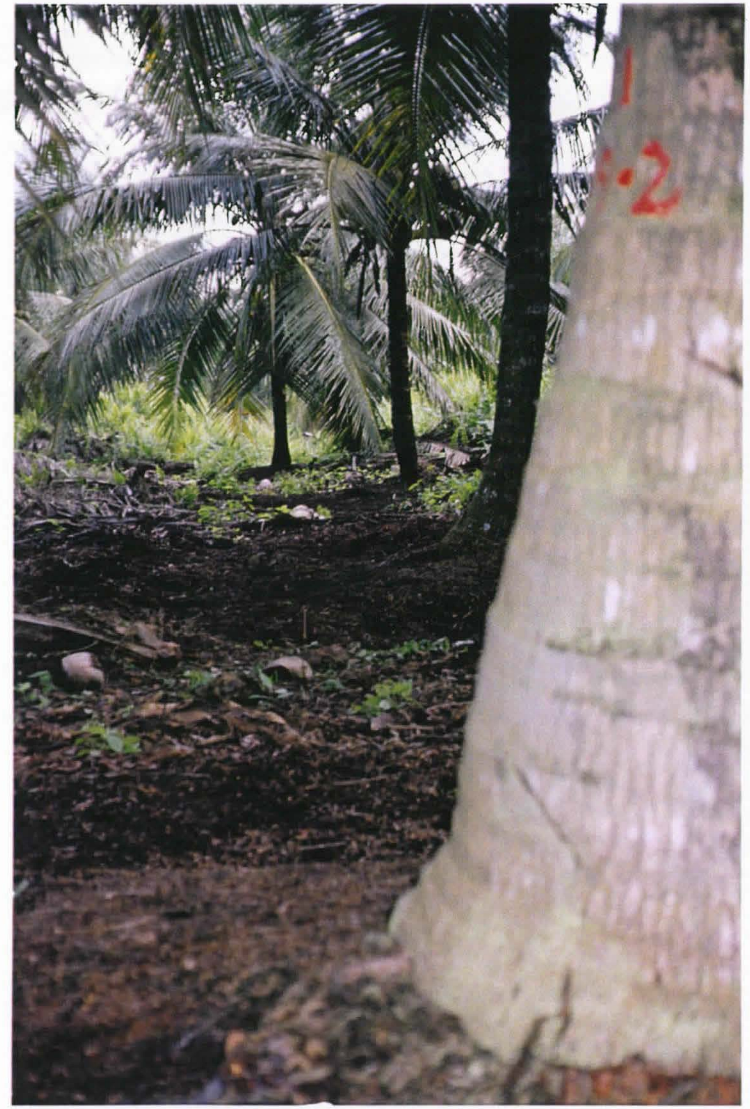


Photo 7 & 8 : ALIGNEMENT TRÈS IRRÉGULIER DES COCOTIERS.
Photo 7 & 8 : VERY IRREGULAR STANDING COCONUT.

TRIALS

I. PROTECTION FROM *Sufetula* AND INCREASING THE MOISTURE IN THE TOPSOIL AT THE FOOT OF THE COCONUT PALMS

I. 1. Purpose

In view of the latest observation results for *Sufetula* caterpillar attacks, it would seem necessary to provide protection from aggression by this pest and from erosion at the foot of the coconut palms, which uncovers the primarily absorbent surface roots. Covering the soil around each coconut palm will increase the moisture content of the first 30 centimetres of soil, down to a depth of 80 cm level with the stem, and limit *Sufetula* attacks.

I. 2. Method

Each elementary plot comprises five rows of five coconut palms. There are three replicates for each experimental treatment.

For soil cover in a 2-m radius around each selected coconut palm, the following elements can be used:

- coconut husks left in the plantation after husking of harvested nuts (photo 1).
- "cocopeat", fibre residues from coconut husk (photo 2).
- dried leaves without the splayed base of the rachis and empty bunches (photo 3).

Monthly insecticide treatments are also planned, alternating the following formulations:

- Dursban 30 ml / 6 litres of water
- Lannate 12 ml / 6 litres of water
- Supracide 20 ml / 6 litres of water

1 ml of adhesive will be added per litre of water (Agristick, Industick or other).

Figures 1 and 2 show the experimental design set up during the mission. The husk and cocopeat trials are being conducted in plot A07-01 and the leaf and empty bunch trial in the South of A07-02; both plots are substantially attacked by the pest.

The usual fertilizer rates will be applied to the soil or directly to the cocopeat or husk; in a ring 1 m from the stem.

I. 3. Observations

Root samples will be taken every three months 80 cm from the stem in two 1 m x 40 cm x 40 cm holes, 1 hole in the planting row, the other in the interrow perpendicular to the planting row. An initial sample was taken before spreading the husk or cocopeat and before the treatments.

An initial nut count, from leaf 10 to the lowest leaf, was made on all nine central palms of each elementary plot when the trial was set up. Subsequent counts were carried out every three months on the same nine central palms in all the elementary plots.

PHOTO 1 : PROTECTION CONTRE L'EROSION ET CONTRE LES ATTAQUES DE *Sufetula* AVEC DE LA BOURRE DE COCO - PROTECTION AGAINST EROSION AND *Sufetula* ATTACKS WITH COCONUT HUSK.

PHOTO 2 : PROTECTION CONTRE L'EROSION ET CONTRE LES ATTAQUES DE *Sufetula* AVEC DU COCOPEAT - PROTECTION AGAINST EROSION AND *Sufetula* ATTACKS WITH COCOPEAT.

PHOTO 3 : PROTECTION CONTRE L'EROSION ET CONTRE LES ATTAQUES DE *Sufetula* AVEC DES PALMES ET DES RAFLES SECHES - PROTECTION AGAINST EROSION AND *Sufetula* ATTACKS WITH DRY FRONDS AND BUNCH STALKS.

Figure 1 : A 07- 01 - HSF 14 - RSUP

Protection against *Sufetula* attacks and improvement of the humidity of the superficial horizon of the soil by the foot of the coconut

C	Control
H	2 layers of coconut husk on 2 m radius around the stem
HI	2 layers of coconut husk + insecticide treatment every month on 2 m radius around the stem
CP	1 layer of 10 cm of cocopeat on 2 m radius around the stem
CPI	1 layer of cocopeat + insecticide treatment every month on 2 m radius around the stem
I	Only Insecticide treatment every month on 2 m radius around the stem

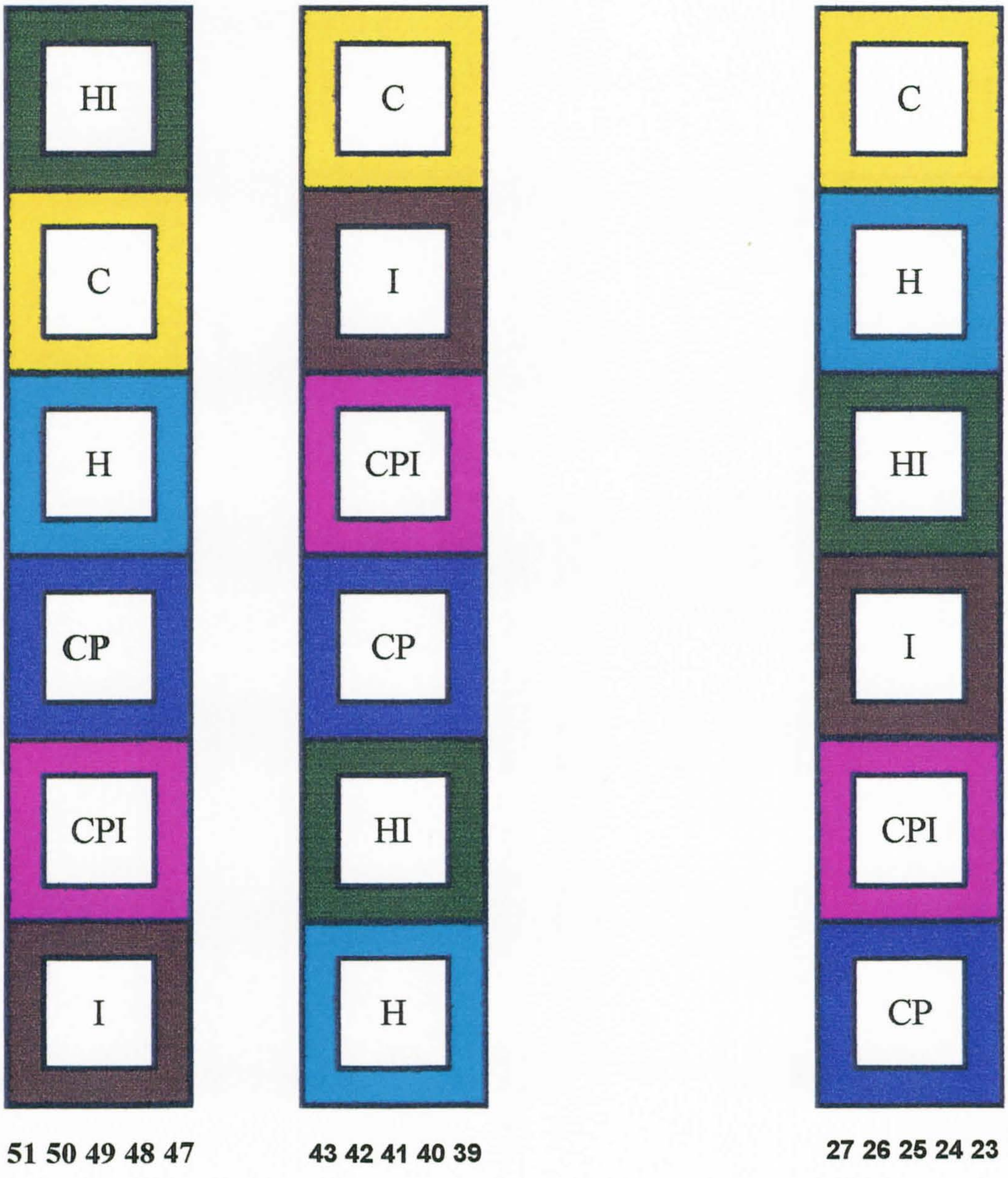
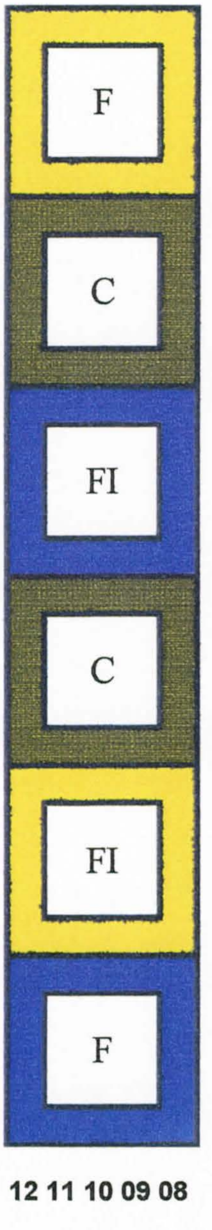


Figure 2 : A 07- 02 - HSF 15 - RSUP

Protection against *Sufetula* attacks and improvement of the humidity of the superficial horizon of the soil by the foot of the coconut

C	**Control**
F	**2 layers of dry fronds and bunch stalks on 2 m radius around the stem**
FI	**2 layers of dry fronds and bunch stalks + insecticide treatment every month on 2 m radius around the stem**



II. TRIAL TO PROTECT AGAINST *Sufetula* AND EROSION

II. 1. Purpose

For new plantings and replantings, the aim is to develop a strategy to counter early *Sufetula* attacks and then to prevent erosion.

II. 2. Method

Each elementary plots comprises five rows of 10 coconut palms. There are six replicates for each of the three experimental treatments.

Treatment A :	- 1st year after planting :	bare soil - manual weeding.
	- 2nd year after planting:	application of a layer of husk or cocopeat in a 1-m radius around the stem.
	- 3rd year after planting:	application of a layer of husk or cocopeat in a 1.5-m radius around the stem.
	- 4th year after planting:	application of a layer of husk or cocopeat in a 2-m radius around the stem.
	- 5th year after planting:	application of 2 layers of husk or cocopeat in a 1-m radius around the stem. Keep this thickness for the entire life of the coconut palm. Slashing of plant cover every 6 months.
Treatment B:	- 1st year after planting :	bare soil - manual weeding.
	- 2nd year after planting:	application of a layer of dried leaves in a 1-m radius around the stem.
	- 3rd year after planting :	application of a layer of dried leaves in a 1.5-m radius around the stem.
	- 4th year after planting :	application of a layer of dried leaves in a 2-m radius around the stem.
	- 5th year after planting :	application of 2 layers of dried leaves in a 1-m radius around the stem. Keep this thickness for the entire life of the coconut palm. Slashing of plant cover every 6 months.

Treatment C: Normal planting with clean circles and a natural plant cover.

The usual fertilizer rates will be applied directly to the cocopeat or husk, 0.5 m from the stem of young palms, then 1 m away around the stem.
When *Sufetula* are noted, each elementary plot could be divided into two subplots of 5 rows x 5 coconut palms; insecticide treatments will then be carried out monthly in one of the two subplots (figure 3).

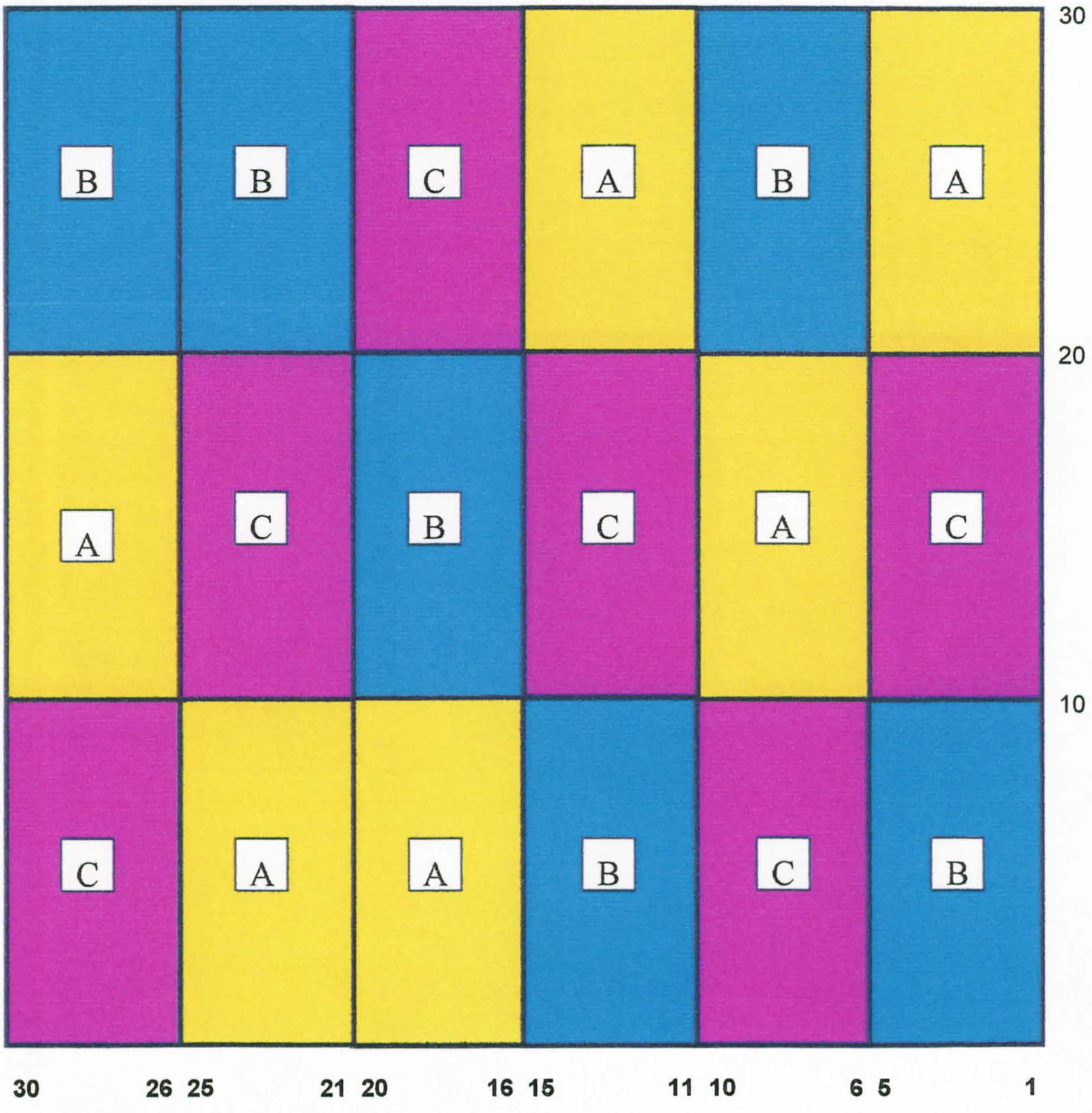
Figure 3 : A07- 01 (Partie nord) - HSF 16 - RSUP

Protection contre *Sufetula* et l'érosion dès le jeune âge

A **Sol nu au départ puis couverture du rond avec de la bourre ou du cocopeat**

B **Sol nu au départ puis couverture du rond avec des feuilles et des rafles sèches**

C **Plantation normale avec une couverture végétale naturelle**



II. 3. Observations

Root samples will be taken in the first years (0 to 4 years) 0.5 m from the stem in a 1 m x 40 cm x 40 cm hole.

The following measurements will also be taken:

- girth every three months
- number of leaves emitted every six months
- length of leaf 4 every 6 months
- height from tip of spear to ground every six months
- leaf analysis every six months
- number of inflorescences per coconut palm
- number of nuts per coconut palm

II.4. Other trials

It would also be worth checking the following 2 to 3-year-old plots at RSUP: 05-00 (April 95); 04-00 (February 95); 03-00 (December 94) and 02-00 (December 94). If there are any *Sufetula* attacks in those plots, a trial should be set up protecting them from the insect with the following experimental treatments:

- Bare soil
- Bare soil + cocopeat or dried leaves in a 1.5-m radius around the stem
- Bare soil + cocopeat or dried leaves in a 1.5-m radius around the stem + insecticide treatment every three months
- Normal plant cover + clean circle
- Normal plant cover + cocopeat or dried leaves in a 1.5-m radius around the stem
- Normal plant cover + cocopeat or dried leaves in a 1.5-m radius around the stem + insecticide treatment every three months
- Insecticide + adhesive once a year
- Insecticide + adhesive twice a year
- Insecticide + adhesive four times a year.

Elementary plot: 5 rows x 5 coconut palms - 6 replicates per treatment.
Observations will be the same as those indicated above for the previous trial.

STUDY OF ROOT DEVELOPMENT ON COCONUT PALMS AT RSUP

(C. JOURDAN)

STUDY OF COCONUT ROOT DEVELOPMENT AT RSUP

(C. JOURDAN)

In our study, we attempted to characterize the architecture and development of coconut palm root systems on peat. To this end, we carried out numerous partial and total excavations and installed devices (rhizotrons) to measure the speed of coconut palm root system development in the field.

I. Description of the coconut palm

Table I summarizes the characteristics (height and number of nuts) of the coconut palms chosen for the different observations (rhizotrons, partial and total excavations).

II. Rhizotrons

Fourteen rhizotrons (Photo 1) have been installed at the foot of coconut palms in plot 07-02. Eight were installed vertically (V rhizo) and six horizontally (H rhizo). The palms were chosen for their yields and their position in the plot. We also chose two high-yielding border palms on clay and six palms (three high and three low-yielding) in the plot, without clay.

The following palms were chosen:
- border, high-yielding palms, V rhizo: 49-01 and 51-01
- plot, high-yielding palms, V and H rhizos: 49-17, 49-05 and 51-04
- plot, low-yielding palms, V and H rhizos: 47-04, 52-03 and 51-13.

Observations were made weekly, on a Monday. The trial is expected to last a year, so as to cover all the seasons.

A month after installing the rhizotrons, only one root has been monitored. Moreover, the root only survived for around a fortnight in contact with the pane of glass. This reflects the poor resumption of root system growth after cutting. **Root elongation at RSUP is apparently very slow.**

III. Partial excavations

Two large trenches (Photo 2) were dug at the foot of four palms (two high and two low-yielders) in two main directions, along the planting row and in the interrow, perpendicular to the row. In each trench, roots were identified and followed as far as their apex. Maximum extension, both horizontal and vertical, of primary roots and extension of the root mat (RIII + RIV) were thus defined for each type of palm.

These large trenches revealed the very abrupt limitation, due to repeated *Sufetula* attacks, of root development on all the coconut palms, whether high or low-yielding (Photos 3 to 6). The horizontal extension of the RI system is limited to between 1 and 2 m (Table II), rarely more (only a few RI exceed 3 m on high-yielding palms), instead of the usual 7 to 9 m on average for primary roots on palms of the same age under non-limiting conditions.

Except for the primary roots of border palm 48-01, the longest RI have been as severely attacked as the others, which reveals the widespread nature of the attacks: there are no zones free of *Sufetula*. However, in the interrow east of border palm 48-01 (Photo 7), where there is a layer of clay on the surface and a large heap of coconut husks nearby, some RI are very long (over 5 m) and have not been attacked (Table II). **The clay and coconut husks would therefore seem to have provided some protection against caterpillar attacks.**

The horizontal extension of the root mat made up of absorbent roots (RIII + RIV) is between 1 and 3.8 m (Table II) depending on the palms and on root position (row, interrow). The root mat is concentrated in the topsoil, between 0 and 30 cm down, and is densest near the coconut stem (Photos 3 to 6).

Vertical root extension is limited by the water table, which was generally 1 m down in plot A07-02 at the time of our observations (November 1997). Primary and secondary roots penetrate a few centimetres into the water table, but do not proliferate. A certain number of RI below the coconut palm penetrate up to 2 m into the water (Photo 8). Their morphology is characteristic of roots living in water: they are white, healthy, active, only slightly branched and only slightly woody.

Moreover, it is truly surprising to note **the existence of a dry zone within an 80-cm radius of the stem, down to a depth of 30 cm**, whereas the water table is just 1 m down. Indeed, most of the absorbent roots in the system are found in this dry zone. Lastly, there is a dry zone just below the stem, down to a depth of 80 cm for some palms (Photos 9 and 10). This dry zone is seen even after heavy rains, and particularly on bare soils. It would be wise to study the physical characteristics (porosity, storage capacity) of this peat, which is extremely degraded near the surface.

IV. Total excavations

Still in plot A07-02, six palms (three high and three low-yielding) were uprooted. Table III gives the results of an exhaustive count of the primary roots found at 50 cm, 10 cm and on the root bole.

The number of primary roots on 10-year-old palms is extremely high, irrespective of the type of palm. In fact, there is no significant difference between high and low-yielding palms, despite the fact that the high-yielders have slightly more roots, particularly palm 53-15. At a distance of 50 cm from the stem, there are some 10 000 RI on average, except for palm 53-15, which has some 30 000 RI (Table III). This is excessive compared to the number of roots on palms of the same age in Vanuatu (5 000 on average), where there are no major constraints on growth. However, it is comparable to the number of RI on 29-year-old palms in Vanuatu!

The number of primary roots increases substantially the further one moves from the root bole (Photo 11). In fact, compared to the number of RI emitted by the palm (RI on the root bole), the number of RI 10 or 50 cm from the root bole is **2.1** or **3.4** times greater on average respectively (Table III). In comparison, the multiplication coefficient for the number of RI emitted between 0 and 50 cm by palms in Vanuatu is just **1.3**!

The increase in the number of RI between 0 and 50 cm from the palm is the result of successive reiterations. These reiterations are generally natural in Vanuatu and result from trauma (*Sufetula* attacks) at RSUP.

The excessive number of RI produced by the palms at RSUP almost certainly leads to over-consumption of sugars (carbohydrates produced by photosynthesis), to satisfy demand from the roots at the expense of the plant's other requirements.

V. General comment on root system condition

On the whole, there are very few, if any, young, white roots or roots with a white apex. The root apexes are round and beige or brown, which reflects either slow growth or no growth at all. Growing roots generally have a white, pointed apex, and the white apical zone is at least 10 cm long, which is not the case at RSUP. Coconut palm root system growth is thus not optimum, but rather "in slow motion" (cf. § VI.1.).

Sufetula attacks on roots generally halt the growth of the attacked root. The root generally produces one relay axis (rarely more) by reiteration, replacing the traumatised root. This axis may in turn be attacked by the caterpillar and can reiterate. The process can be repeated many time over, leading to complex, highly branched structures (Photo 12). These branched structures are largely if not totally ineffective in their uptake function, as they primarily comprise RI (by reiteration) rather than RII, which usually bear absorbent roots (RIII + RIV). Furthermore, there is a reduction in diameter between the initial root and the reiterated roots at the end of the line. This almost certainly means poorer conduction throughout the system.

The root system of the coconut palms at RSUP seems to be abnormally branched, with a very dense RI network, a small proportion of RII poorly distributed through the soil and a root mat limited to the topsoil.

The cost of sugar upkeep in such a system is undoubtedly prejudicial to the coconut palms, which consequently develop a relatively limited uptake capacity (water and nutrients).

It would be interesting to quantify this energetic cost in future, along with the uptake capacity of the different roots, notably by measuring sap flow, once the technique is fully developed.
Sap, containing water and minerals, travels from the roots towards to the aerial parts of the coconut palm. Its flow is altered somewhat, or at least quite perturbed in these structures (Photo 13 and Figure 1). The flow of sap, containing assimilates, is reversed, i.e. from the aerial parts to the living organs, in this case the roots. It is clear that sap circulation to the growing organs will be substantially altered, and it is easy to see that there is pointless expenditure of assimilates transported to the numerous roots that are either no longer growing or actually dead (Figure 1).

Primary root diameter has also been studied (Table IV), revealing that neither palm vigour (in terms of the number of nuts borne) nor the direction of RI growth (row/interrow) has any effect on RI diameter. Mean RI diameter varies between individuals, irrespective of their yields, and is not significantly different for a given individual depending on root growth direction (row/interrow).

VI. Histological observations

VI.1. Anatomical characterization of the apexes of "slow-growing" roots

During our field observations, we identified three categories of growing root apexes: white, pointed apexes growing well (Photo 14); brown apexes growing slowly, if at all, and pointed (Photo 15); or round (Photo 16). The last two categories are in the majority at the plantation, reflecting slow root system activity at the time of our observations (November 1997). However, the most active roots (white, pointed apex) have substantial amounts of polyphenols that accumulate in their cells (Photo 17). This polyphenol accumulation is synonymous with physiological resistance on the part of the plant to an aggression, in this case *Sufetula* attacks.

VI.2. Anatomical characterization of *Sufetula* attacks

The caterpillar penetrates into coconut palm roots by boring a hole (Photo 18) near the apex, in the soft, not yet woody tissues. It moves through the root (Photo 19) by primarily eating the tissues of the cortical parenchyma and sometimes the conductive tissues in the central pith (Photos 20 and 21). As it moves, the caterpillar leaves behind it more or less digested excreta (Photos 22 and 23). Moreover, the caterpillar's digestive tube contains pieces of plant tissue whose structure is unmodified (Photo 24) and which will be excreted almost intact (Photos 18 and 22). This bears witness to the caterpillar's continuous progress and consumption in the root; it may also leave one root to attack another. During its development, a single caterpillar can attack several coconut palm roots. This may partly explain the fact that the parasite is not found in large numbers in the soil, whereas numerous roots are attacked.

VI.3. Presence of nematodes in coconut palm roots at RSUP

On observing histological cross sections, we saw nematodes in coconut palm roots for the first time. We located nematodes in various parts of the roots:
- in the cap of a healthy, growing secondary root (Photo 25)
- in the zone mined by *Sufetula,* along with a large colony of bacteria (Photo 26)
- in the tissues of the cortical parenchyma, near the apex of an RI, piercing a pecto-cellulose wall (Photo 27).

The presence of these worms in several roots taken at random in plot K03-01, either attacked by *Sufetula* or not, shows that population levels are considerable.

It is therefore important to identify the parasite in the near future, to determine whether it is truly pathogenic.

VII. Piezometers and stomatal opening

A network of 33 piezometers has been installed in plot A07-02 in two perpendicular lines, one running North-South starting from the secondary canal and the other East-West between two tertiary canals. Weekly records are currently being kept.
At the same time, stomatal opening is being measured on the palms near the piezometers.
The initial results show that the water table is stable at around 1 m below the surface, throughout the network.

VIII. Computer graphic simulations

Given the limits of horizontal and vertical coconut palm root system development at RSUP, the constraints can be simulated on computer using the softwares developed at CIRAD, particularly for the root systems of oil palm (Jourdan, 1995), cocoa and coconut (Colas, 1997).
With simulation, it is possible to visualize a virtual stand comparable to the RSUP plantation, keeping to the same planting design (Photos 28 to 30).

Additional measurements of root biomass will have to be made in the field so as to estimate the total root biomass of a plot affected by *Sufetula* attacks, by simulation.

References

Jourdan C., 1995. Modélisation de l'architecture et du développement du système racinaire du palmier à huile. Doctorate thesis, Université de Montpellier II, 245 p.

Colas H., 1997. Association de cultures cocotier cacaoyer. Modélisation de leur système racinaire. Etudes préliminaires sur l'interaction racinaire et la consommation en eau des deux plantes. Doctorate thesis, Université de Montpellier II, 260 p.

IX. Observations on oil palms at BRS

During my time at the BRS oil palm plantation, I was able to confirm that there were *Sufetula* in the soil, but population levels were lower than at RSUP, and above all, there were relatively few signs of attacks on the root systems.

The plot visited is four years old. The palms are vigorous (stem girth >1 m), but with very few male inflorescences, and yields seem to vary substantially from palm to palm.

We found numerous buried tree stumps from the former forest cover. The peat is light in colour, very moist and highly aerated, and the surface is not degraded like it is at RSUP. The interrows contain very large ferns (over 1 m tall), and the topsoil is very rich in organic matter.

The primary roots are extremely long (3 to 6 m) for four-year-old palms (4 m on average for palms in the Ivory Coast). The number of RI per palm is high: 1 200 on average at BRS compared to around 300 in the Ivory Coast. There were numerous RIII that were very fine (diameter between 0.04 and 1 mm), dry (80% of them) and uniformly distributed between 0 and 1 m down. The RI extend as far as the water table, which is 1 m down as at RSUP. There is no root mat in the topsoil, as the palms are still young.

Some RI are black between 0 and 2 m from the stem, which is surprising for such young palms. This black colour is normally the result of suberification of the hypodermis, and characterizes roots around ten years old.

In short, the root system of the oil palms at BRS is vigorous and growing well, with good horizontal extension of up to 6 m and vertical extension as far as the water table (1 m down), with no apparent trauma due to *Sufetula* attacks. The caterpillar can be seen, but does not seem to have caused any damage for the time being.

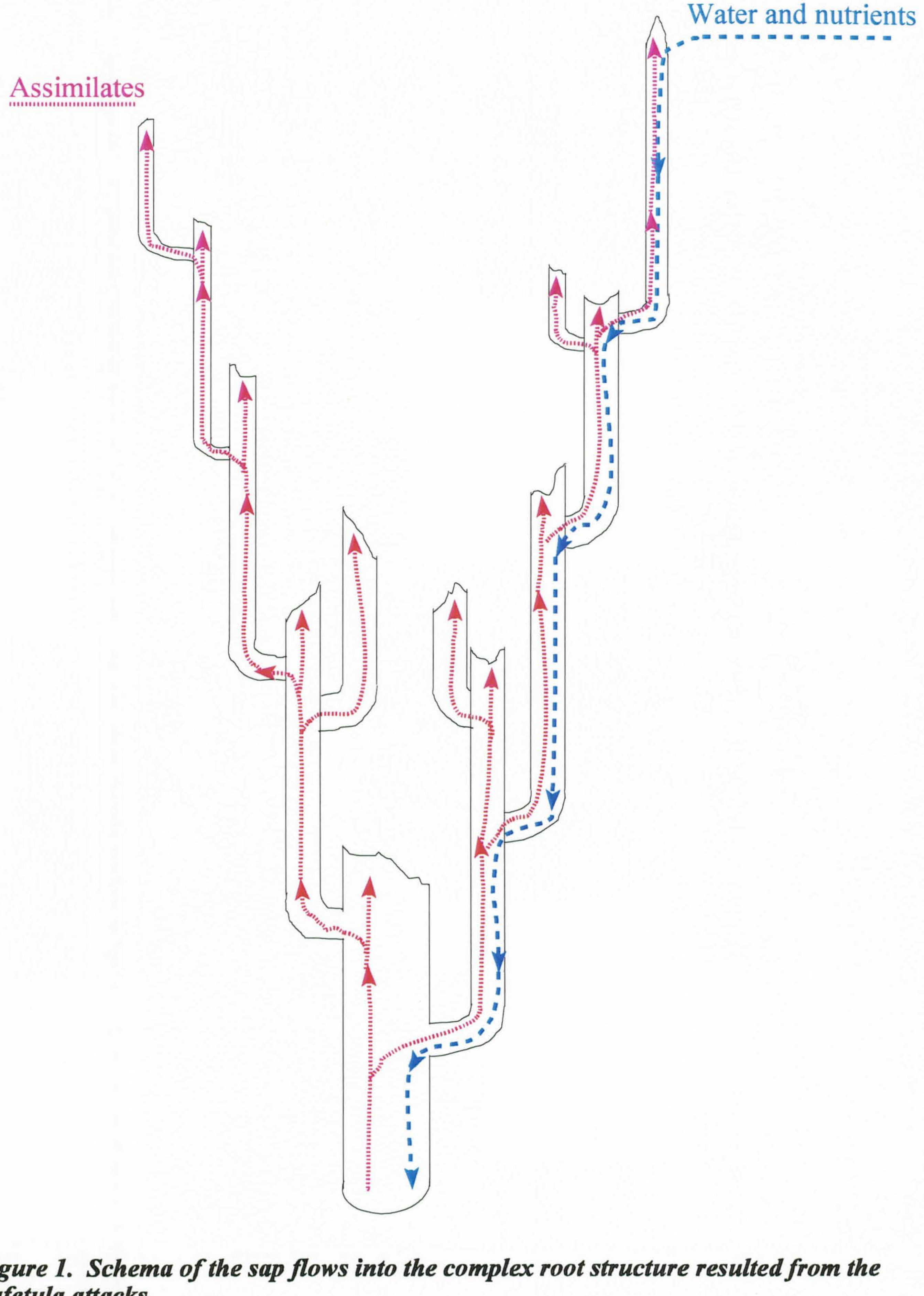


Figure 1. Schema of the sap flows into the complex root structure resulted from the Sufetula attacks.

TABLE I. Characteristics (height and number of female flowers or nuts) of the different coconuts chosen for the root observations.

			Height		Number of female flowers or nuts in each leaf rank																		
			(m)	TOTAL	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28
TOTAL EXCAVATIONS	***Good-looking coconuts***	Tree 53-15	**7.78**	**178**	21	20	11	10	9	10	9	10	13	7	11	10	14	10	13				
		Tree 53-26	**7.52**	**137**	18	18	9	0	5	7	7	1	11	2	13	8	3	8	13	14			
		Tree 53-30	**7**	**154**	15	18	0	8	8	8	9	12	15	11	13	15	5	7	10				
	Bad-looking coconuts	Tree 53-19	**4.52**	**41**	7	2	5	5	3	6	2	2	4	1		3	1						
		Tree 53-43	**5.13**	**57**	8	5	1	5	7	5	8	5	6	2	4	1							
		Tree 53-47	**4.96**	**41**	5	4	2	1	3	2	1	5	3	7	4	2	2						
RHIZOTRONS	***Good-looking coconuts***	Tree 51-01	**7.7**	**225**	33	32	7	11	14	13	11	14	16	13	5	14	14	9	11	8			
		Tree 49-01	**7.51**	**209**	22	17	6	12	14	16	14	17	11	14	5	15	14	6	11	15			
		Tree 49-17	**6.3**	**150**	13	18	7	5	7	8	5	10	11	13	11	9	11	10	12				
		Tree 49-05	**6.45**	**111**	12	7	6	9	13	11	11	11	9	6	7	9							
		Tree 51-04	**6.95**	**126**	15	10	6	13	7	10	7	10	9	6	9	7	7	10					
	Bad-looking coconuts	Tree 52-03*	**6.91**	**112**	22	10	2	12	16	11	16	8	8	6	1								
		Tree 51-13	**4.32**	**58**	10	9	3	3	1	7	5	5	7	3	3	2							
		Tree 47-04	**4.62**	**59**	7	8	3	5	6	8	5	3	3	5	2	3	0	1					
PARTIAL EXCAVATIONS	***Good-looking coconuts***	Tree 48-01	**9.12**	**260**	25	21	7	11	12	15	17	14	17	19	14	13	11	12	19	19	13	0	1
		Tree 49-04	**8.06**	**148**	25	18	9	8	6	11	3	9	15	8	9	9	6	12					
	Bad-looking coconuts	Tree 48-20	**5.87**	**84**	16	14	6	8	11	2	2	3	5	5	4	3	3	2					
		Tree 49-16	**5.26**	**42**	7	2	1	6	4	5	2	1	4	2	5	3							

** (Not so bad)-looking coconut*

TABLE II. Statement of the horizontal layout of the primary roots of coconuts in the 07-02 plot. State : S = attacked by Sufetula ; M = death ; C = in growth. Length and depth in meter.

	Good-looking coconuts												***Bad-looking coconuts***												
	Tree 48-01						Tree 49-04						Tree 48-20						Tree 49-16						
	in the line (N)			inter-row (E)			in the line (S)			inter-row (E)			in the line (S)			inter-row (W)			in the line (S)			inter-row (E)			
	Length	State	Depth	Length	State	Depth	Length	State	Depth	Length	State	Depth	Length	State	Depth	Length	State	Depth	Length	State	Depth	Length	State	Depth	
Total of the longest primary roots (RI)	2.98	M	0.12	4.5	M	0.27	3.7	S	0.1	3.15	S	0.10	2.46	S	0.22	1.76	M	0.4	2.39	S	0.1	2.56	S	0.1	
	4.47	M	0.05	7.75	C	0.55	1.3	S	0.4	1.87	S	0.40	2.4	S	0.22	1.91	S	0.05	1.99	S	0.32	2.61	S	0.08	
	2.91	S	0.42	8.55	C	0.95	1.3	M	0.64	1.8	C	0.30	3.25	M	0.6	2	S	0.04				2.33	S	0.09	
	2.67	S	0.19	5.12	C	0.15				1.9	S	0.50	3.5	C	0.09							1.9	M	0.21	
	2.36	S	0.52	3.22	M	0.15				1.95	M	1.00	6	M	0.01										
	2.41	S	0.36	2.69	C	0.66				1	S	0.80	5.6	S	0.05										
	2.18	S	0.6	5.08	M	0.41																			
	2.89	S	0.17																						
	3.02	M	0.16																						
	4.82	C	0.03																						
	2.4	M	0.1																						
Mean	3.01		0.25	5.27		0.45	2.10		0.38	1.95		0.52	3.87		0.20	1.89		0.16	2.19		0.21	2.35		0.12	
Standard deviation	0.82		0.19	2.01		0.27	1.13		0.22	0.63		0.30	1.43		0.20	0.10		0.17	0.20		0.11	0.28		0.05	***mean***
Max. length of the other RI	**1.7**			**2**			**1**			**2**			**2**			**0.93**			**1.9**			**1.5**			**1.63**
Layout of the root mat (RIII+RIV)	**1**			**1.27**			**1**			**1.8**			**3.8**			**2.4**			**2.44**			**2**			**1.96**

TABLE III. Number of roots on good- and bad-looking coconuts. nb: number of roots; coef.: increase coefficient.

	(good-looking coconuts)						(bad-looking coconuts)					
Dist. from the	tree 53-15		tree 53-26		tree 53-30		tree 53-19		tree 53-43		tree 53-47	
root bole (cm)	nb	coef.	nb	coef.	nb	coef.	nb	coef.	nb	coef.	nb	coef.
50	30736	x 1.9*	12970	x 1.5	9360	x 1.5	11148	x 1.5	9665	x 1.7	8235	x 1.7
10	16455	x 3.0**	5804	x 1.8	6296	x 1.7	7250	x 2.1	5563	x 2.4	4617	x 1.6
0	5408	x 5.7***	4640	x 2.8	3632	x 2.6	3465	x 3.2	2331	x 4.1	2786	x 3.0

** (nb roots at 50 cm)/(nb roots at 10 cm) ; ** (nb roots at 10 cm)/(nb roots at 0 cm) ; *** (nb roots at 50 cm)/(nb roots at 0 cm).*

TABLE IV. Diameter of the primary roots of the good- and bad-looking coconuts in the line and the inter-row. N : north ; S : south ; E : east ; W : west.

		Dir. of growth	mean (cm)	DIAMETER OF THE PRIMARY ROOTS OF THE COCONUTS (cm)														
good-looking coconuts	tree 48-01	in the line (N)	0.81 ± 0.13	0.83	0.86	0.76	0.71	0.75	0.76	0.7	0.83	0.86	0.99	1.15	0.82	0.9	0.59	0.68
		inter-row (E)	0.78 ± 0.18	0.78	0.66	0.86	0.66	0.81	0.66	0.63	0.66	0.9	0.64	1.18	0.73	0.62	1.17	
	tree 49-04	in the line (S)	0.66 ± 0.07	0.76	0.68	0.8	0.61	0.63	0.63	0.77	0.67	0.67	0.54	0.74	0.58	0.64	0.6	0.59
		inter-row (E)	0.67 ± 0.07	0.73	0.7	0.72	0.77	0.66	0.68	0.59	0.75	0.7	0.73	0.72	0.67	0.54	0.6	0.56
bad-looking coconuts	tree 48-20	in the line (S)	0.81 ± 0.13	0.94	0.83	0.96	0.64	0.88	0.98	1	0.78	0.87	0.87	0.68	0.6	0.71	0.67	0.7
		inter-row (W)	0.75 ± 0.16	1.14	0.86	0.93	0.98	0.68	0.64	0.76	0.64	0.65	0.65	0.58	0.63	0.8	0.56	
	tree 49-16	in the line (S)	0.66 ± 0.09	0.63	0.6	0.74	0.88	0.74	0.7	0.59	0.7	0.57	0.62	0.68	0.51	0.53	0.69	0.66
		inter-row (E)	0.67 ± 0.13	0.83	0.58	0.99	0.81	0.52	0.65	0.74	0.66	0.62	0.62	0.71	0.46	0.51	0.73	0.65

LEGENDS

Photo 1. Rhizotron in vertical position in plot 07-02.

Photo 2. Trench digged along the row, till 1 m depth.


1


2

LEGENDS

Photo 3. Root system of a good-looking coconut (n° 49-04). Trench along the row.

Photo 4. Root system of a bad-looking coconut (n° 49-16). Trench along the inter-row.

Photo 5. Root system of a good-looking coconut (n° 48-01). Trench along the row.

Photo 6. Root system of a bad-looking coconut (n° 48-20). Trench along the row.


3


4


5


6

LEGENDS

Photo 7. Root system of a good-looking coconut (n° 48-01). Trench along the inter-row where roots can measure 8 m long.

Photo 8. White roots growing in water under a bad-looking coconut. Maximum depth of rooting : 1 m80.


7


8

LEGENDS

Photo 9. Focus on the upper soil layers with the roots inside, 40 cm from the coconut and from surface to 60 cm depth. Note the absorbent roots (small ones) near the surface (0-15 cm).

Photo 10. Note the dry area around the coconut in surface and also till 80 cm depth.

9

10

LEGENDS

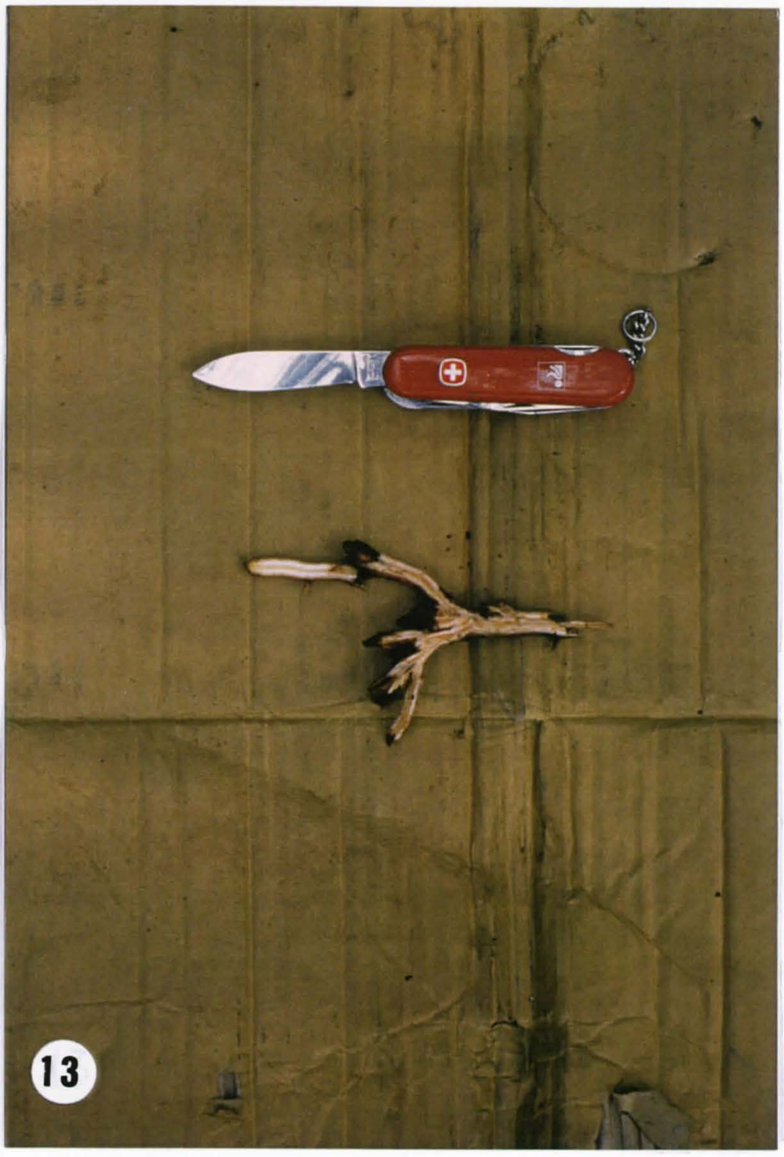
Photo 11. A quater of root system of a bad-looking coconut. Note the increase of the number of primary roots in a distance of 50 cm (between the root soil-plate (white) and 50 cm from it).

Photo 12. Complex root structure resulting from successive attacks performed by *Sufetula*.

Photo 13. Focus on the anatomy of the complex root structure. Note that the roots are still alive.

11

12



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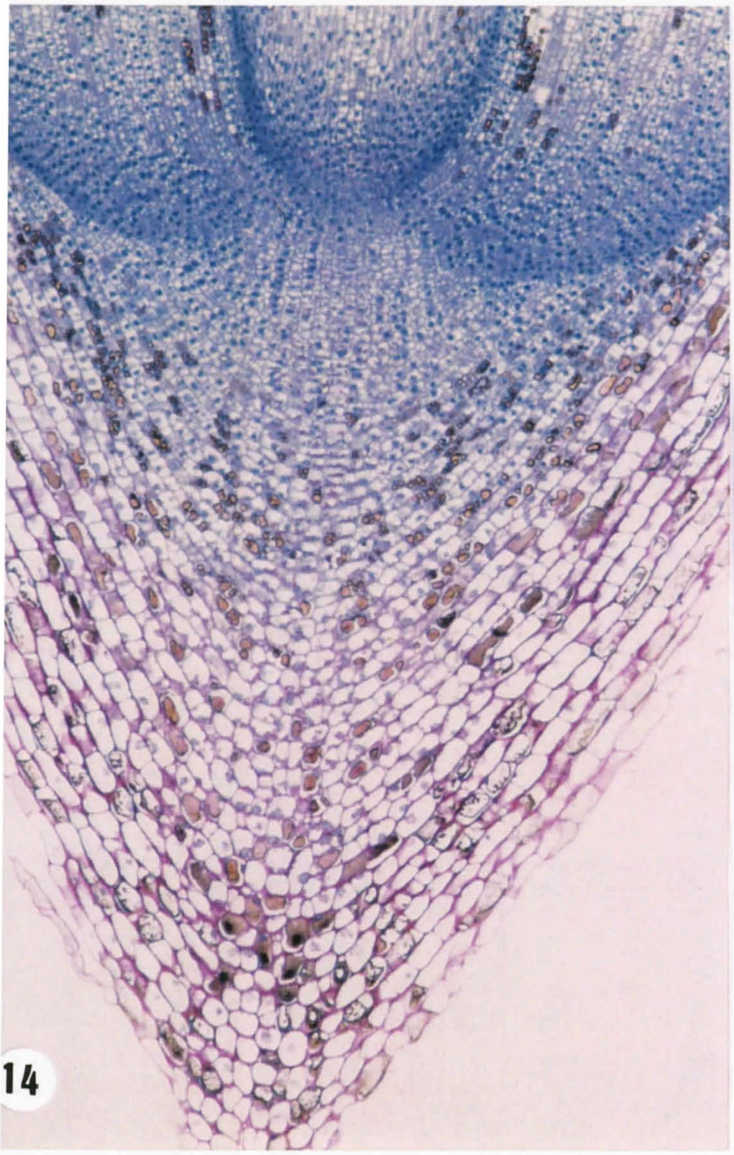
LEGENDS

Photo 14. Longitudinal section of a white and sharp apex of an healthy primary root.

Photo 15. Longitudinal section of a brown and sharp apex of an healthy primary root.

Photo 16. Longitudinal section of a brown and round apex of an healthy primary root.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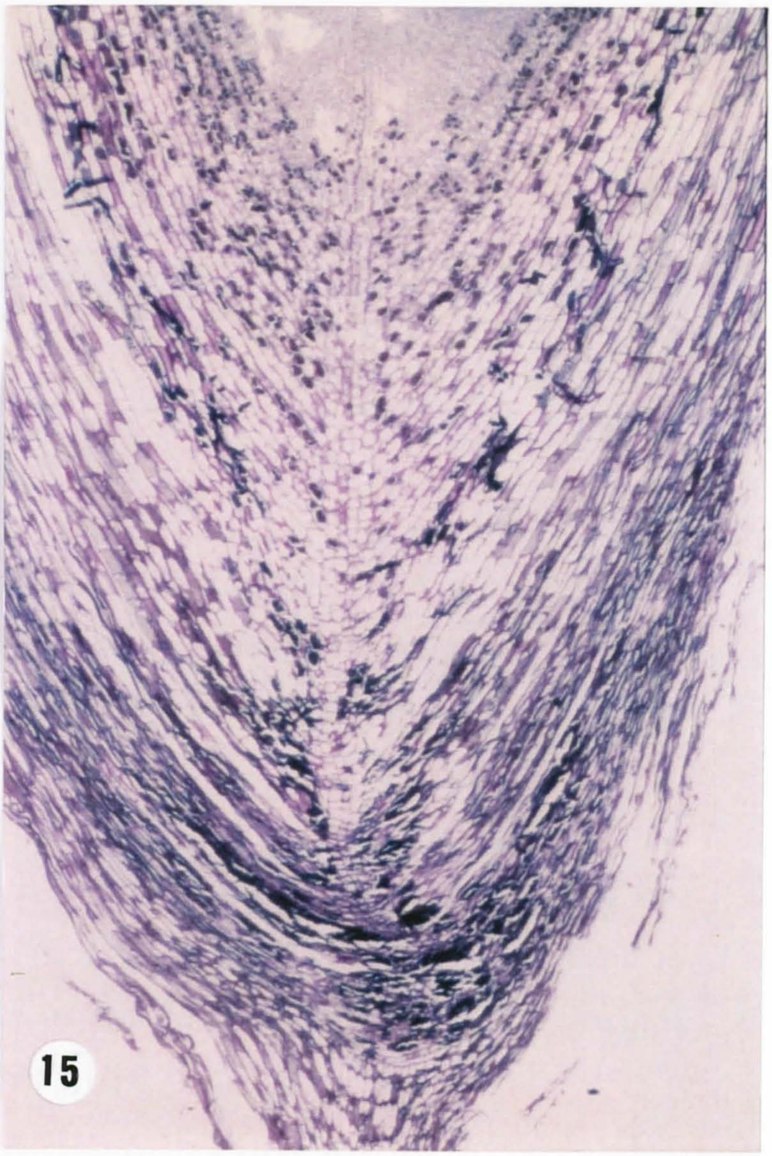
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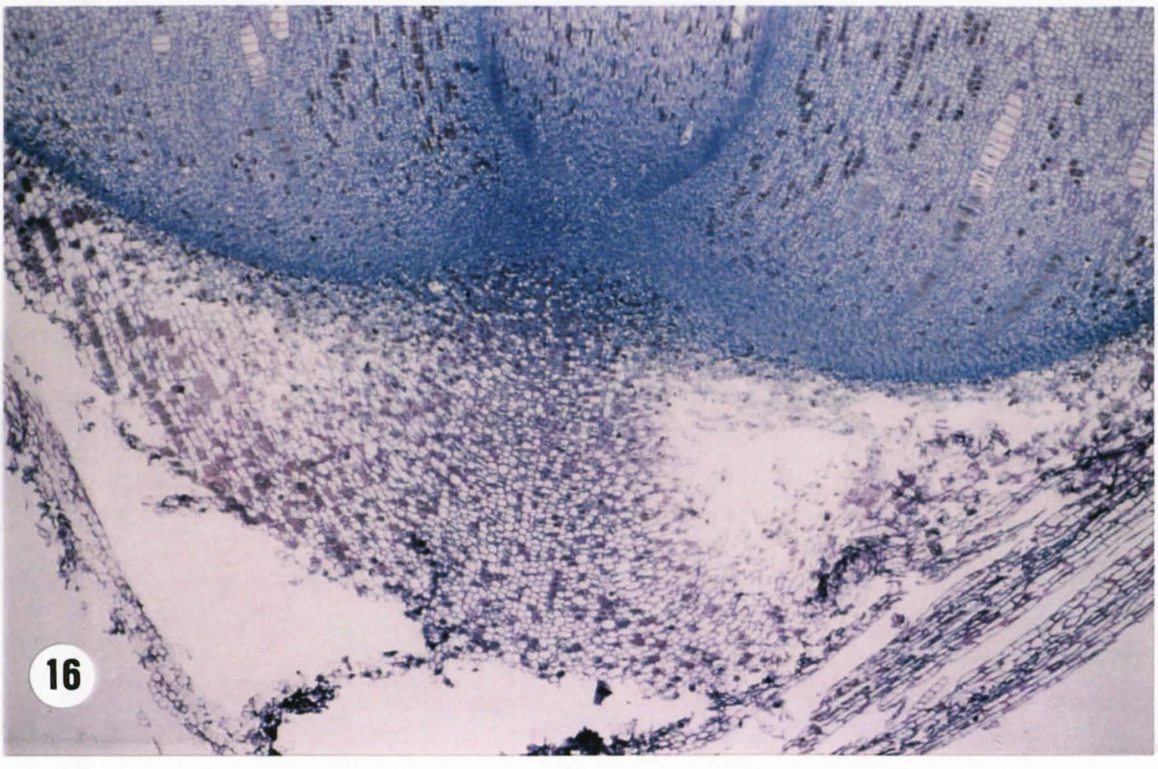
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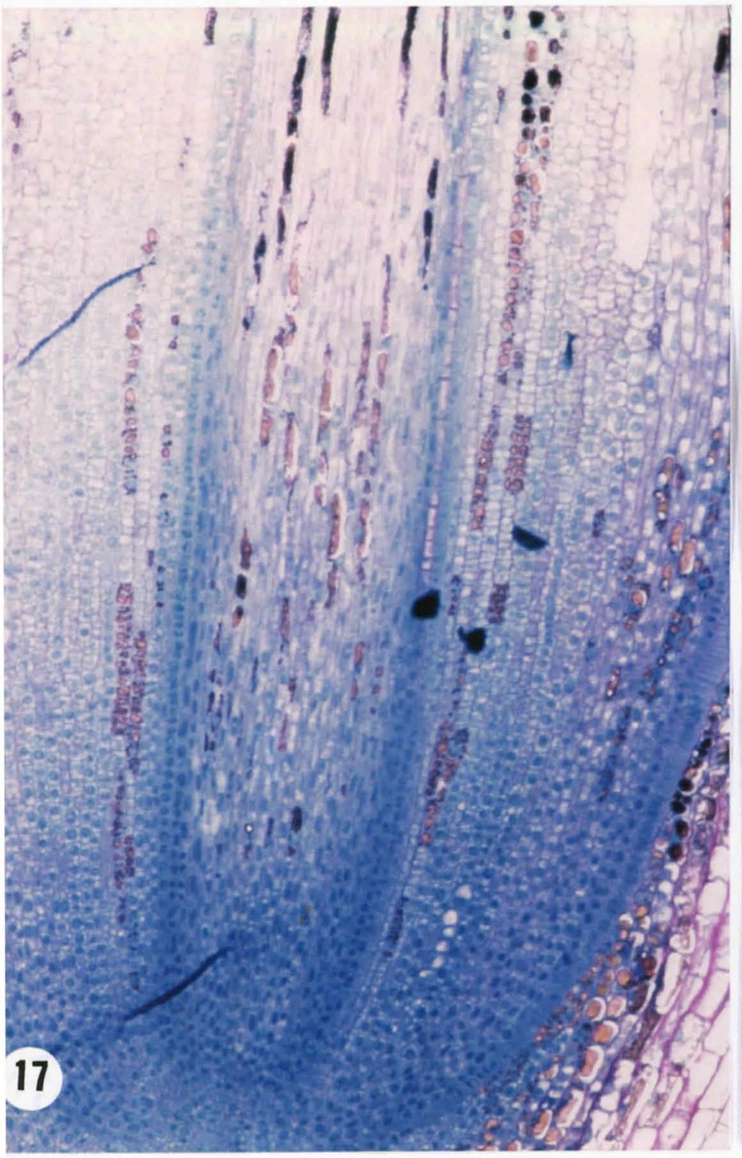
LEGENDS

Photo 17. Longitudinal section of a white and sharp apex of an healthy primary root. Note the presence of polyphenol storage (in brown) in many parts of the root.

Photo 18. Longitudinal section of an attacked primary root. Note the entrance hole performed by *Sufetula* and its numerous dejections.

Photo 19. *Sufetula* inside the cortical parenchyma of a secondary root. Longitudinal section.



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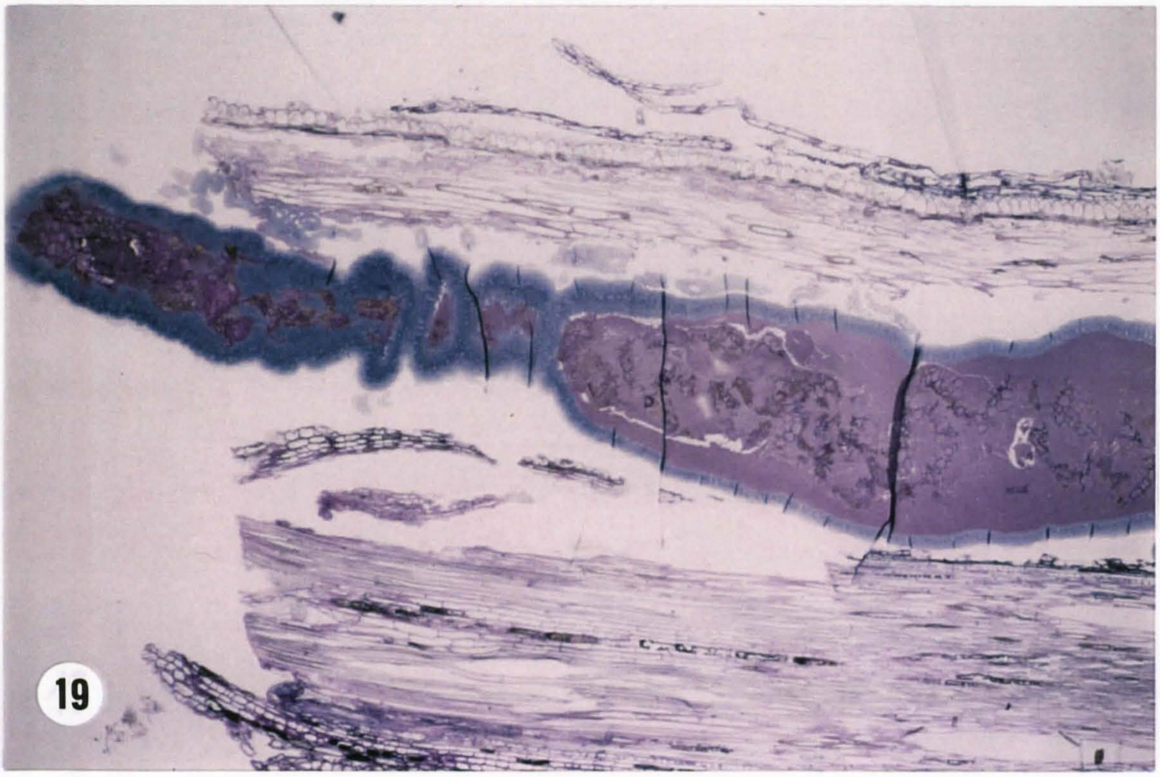

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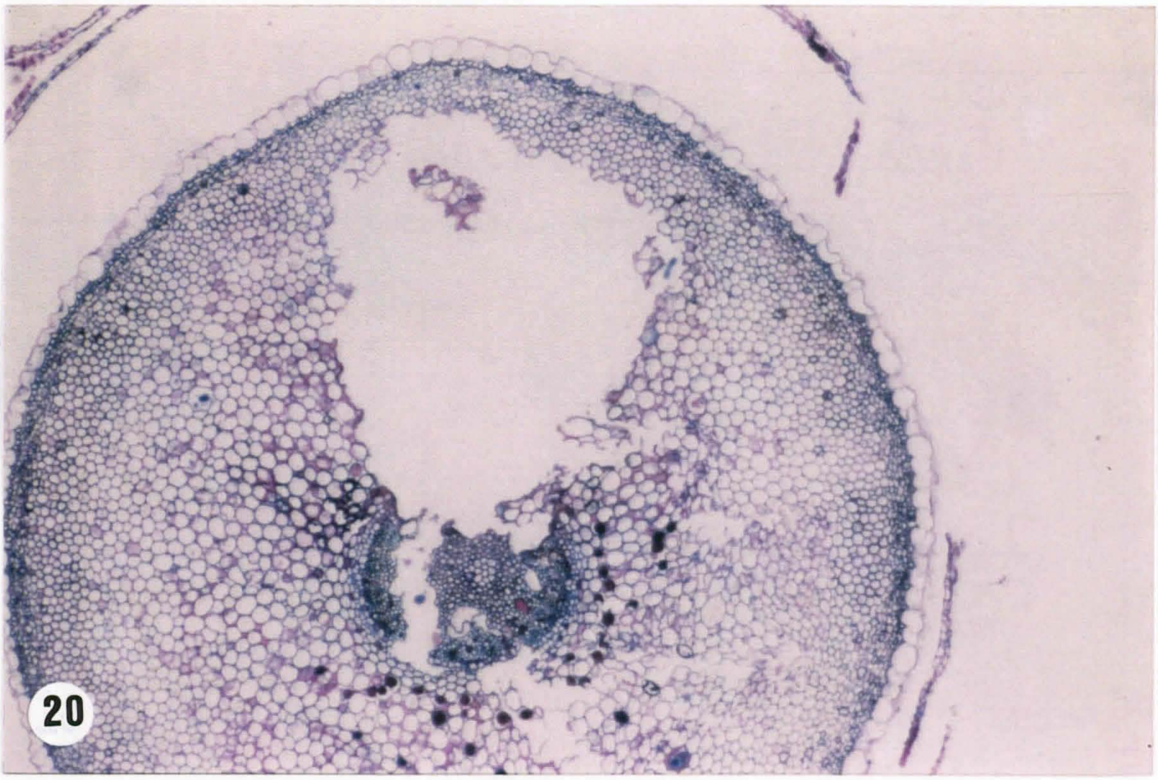
LEGENDS

Photo 20. Hole made by *Sufetula* inside the cortical parenchyma of a secondary root.Cross section.

Photo 21. Hole made by *Sufetula* inside the apex of a primary root. Longitudinal section.



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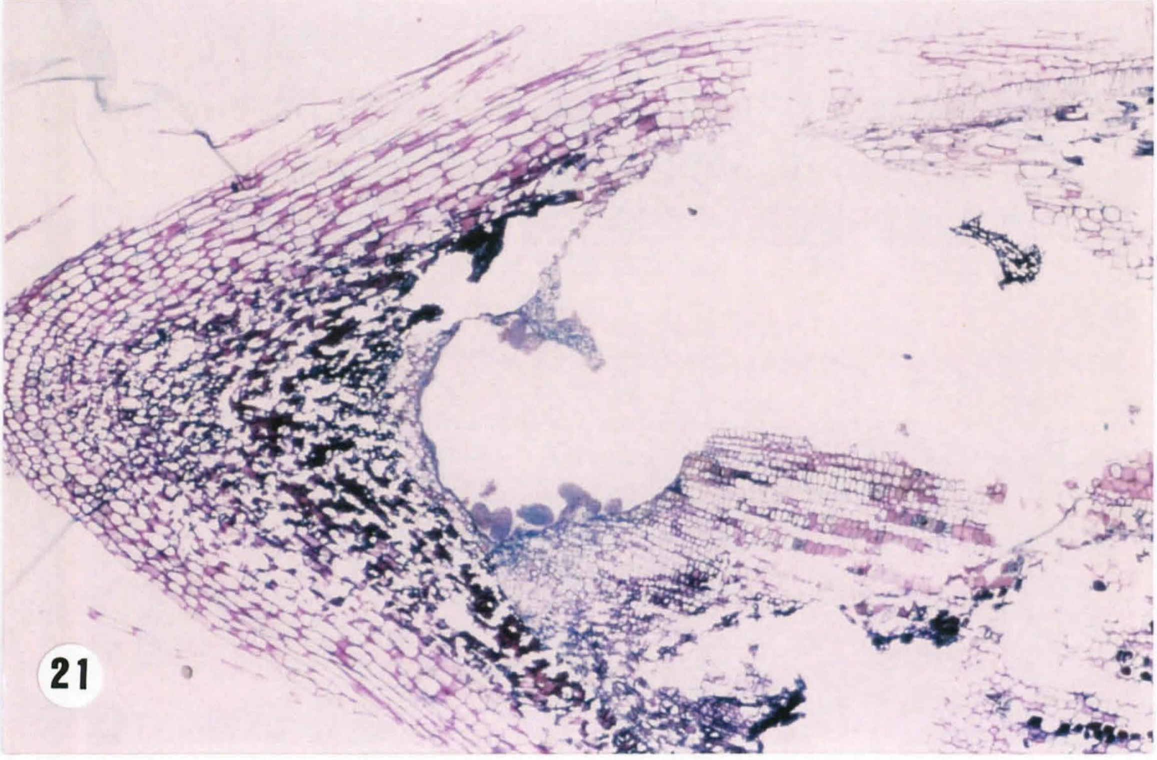

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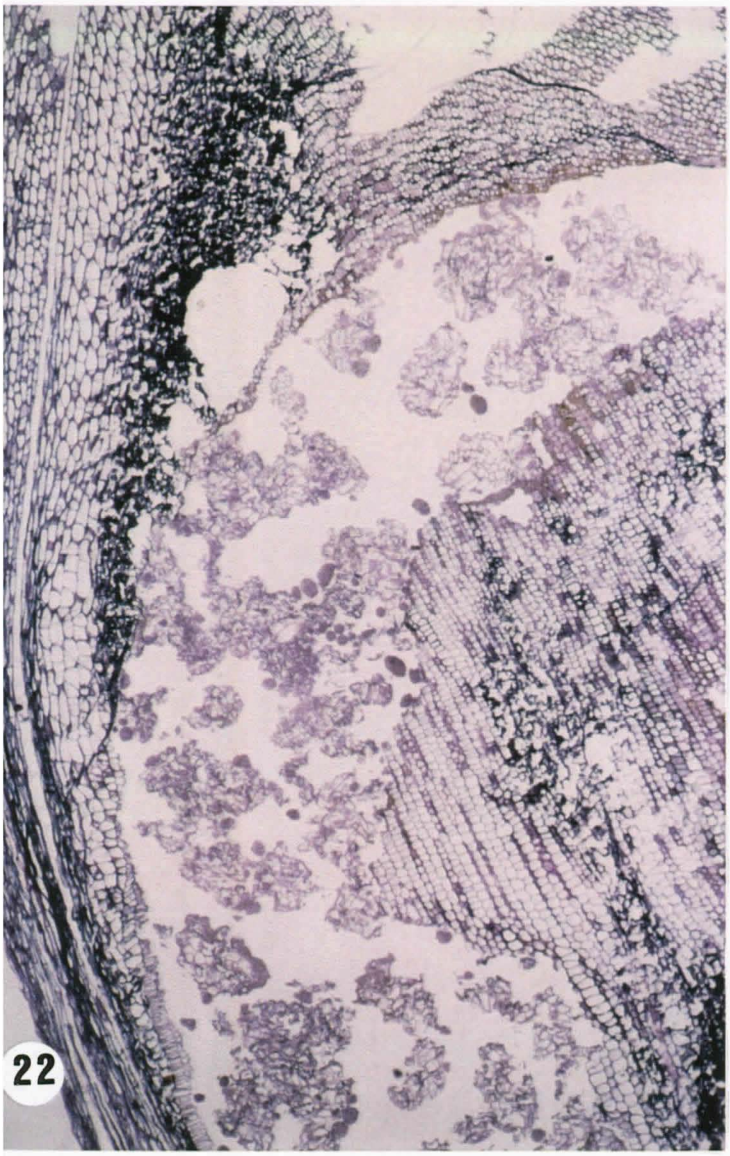
LEGENDS

Photo 22. Dejections of *Sufetula* inside a primary root. Longitudinal section.

Photo 23. Focus of the *Sufetula* dejections inside a primary root. Longitudinal section.

Photo 24. Longitudinal section of the alimentary canal of *Sufetula* inside a secondary root. Note the parenchyma cells still organised inside the alimentary canal.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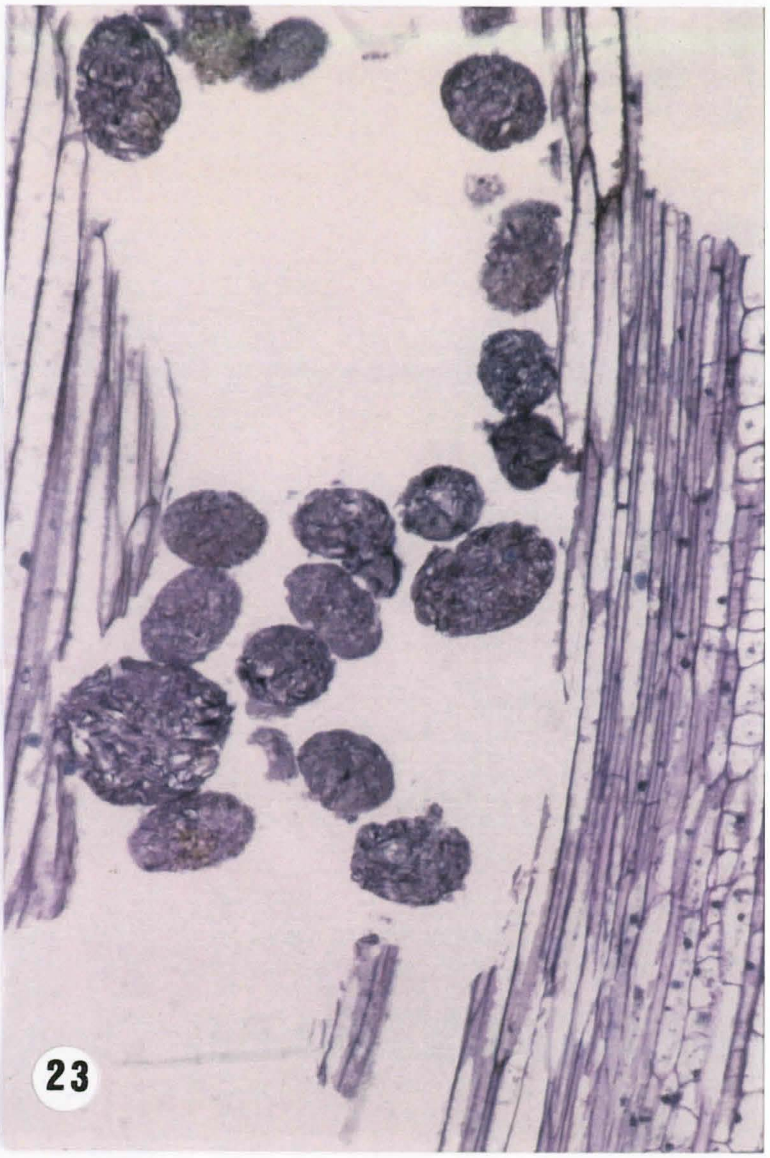
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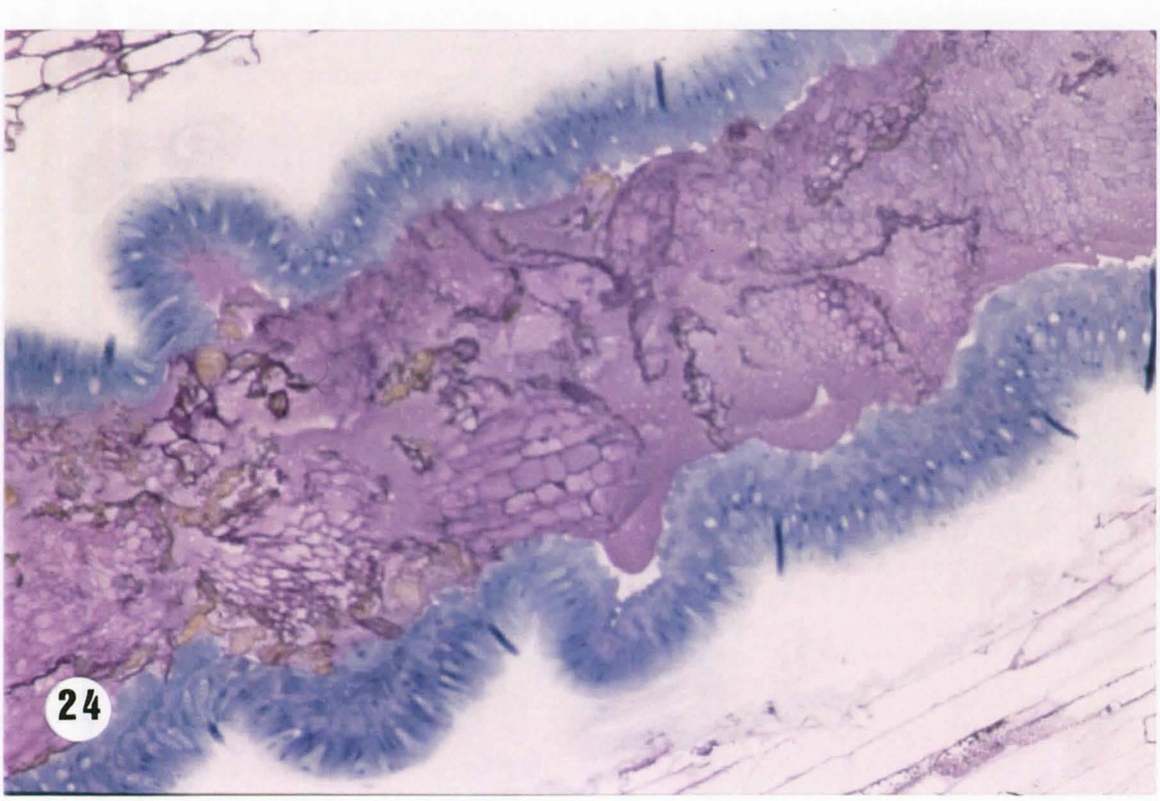
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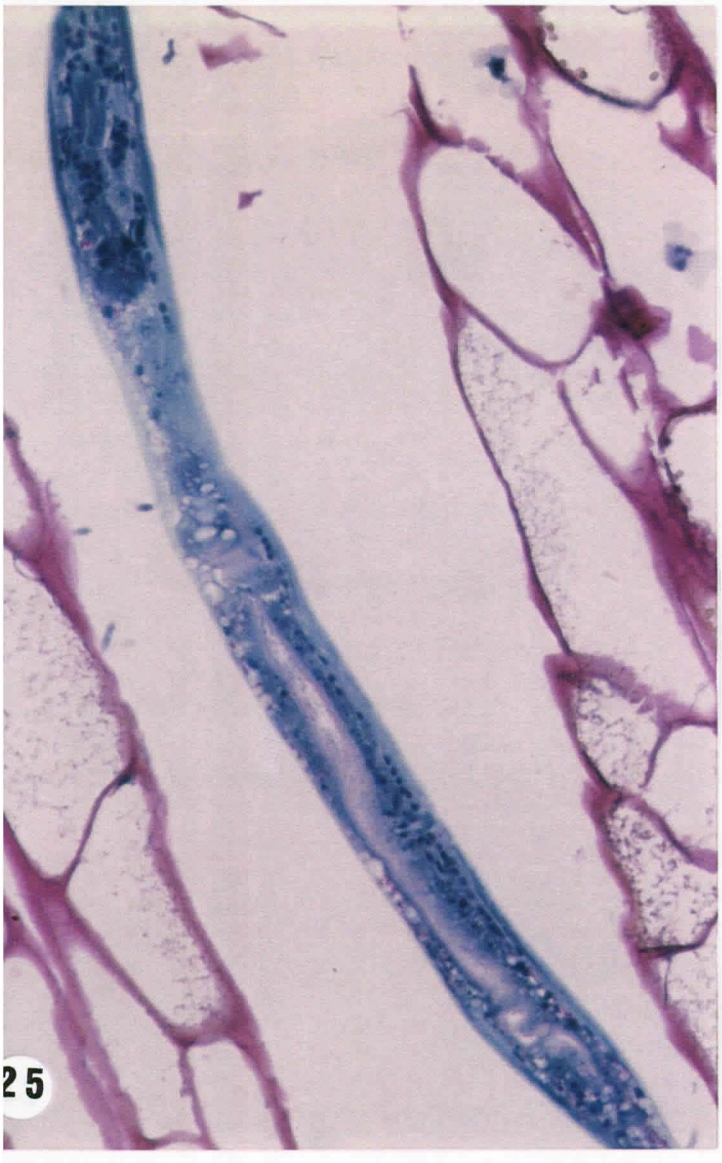
LEGENDS

Photo 25. Longitudinal section of a nematod inside the root cap of a secondary root.

Photo 26. Longitudinal section of a nematod inside a primary root. Note the presence of many bacteria (in grey) by side of the nematod.

Photo 27. Longitudinal section of the head of a nematod which go through the cell wall, inside the apex of a primary root.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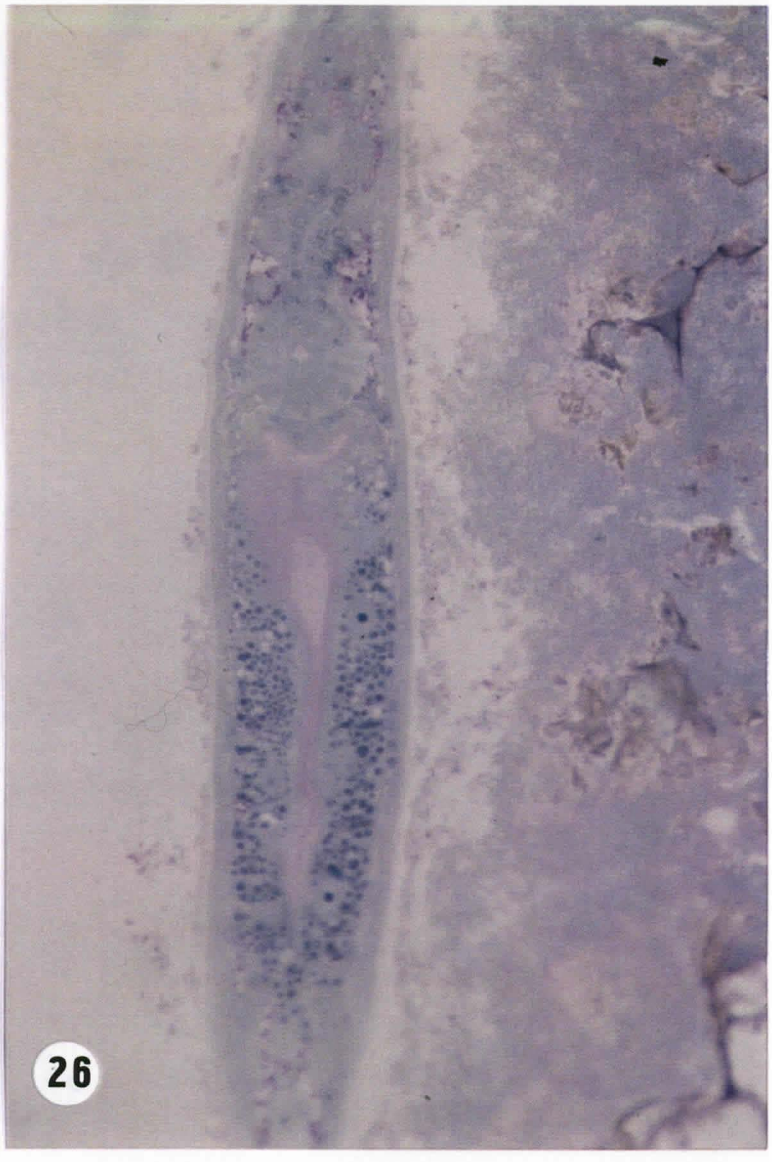
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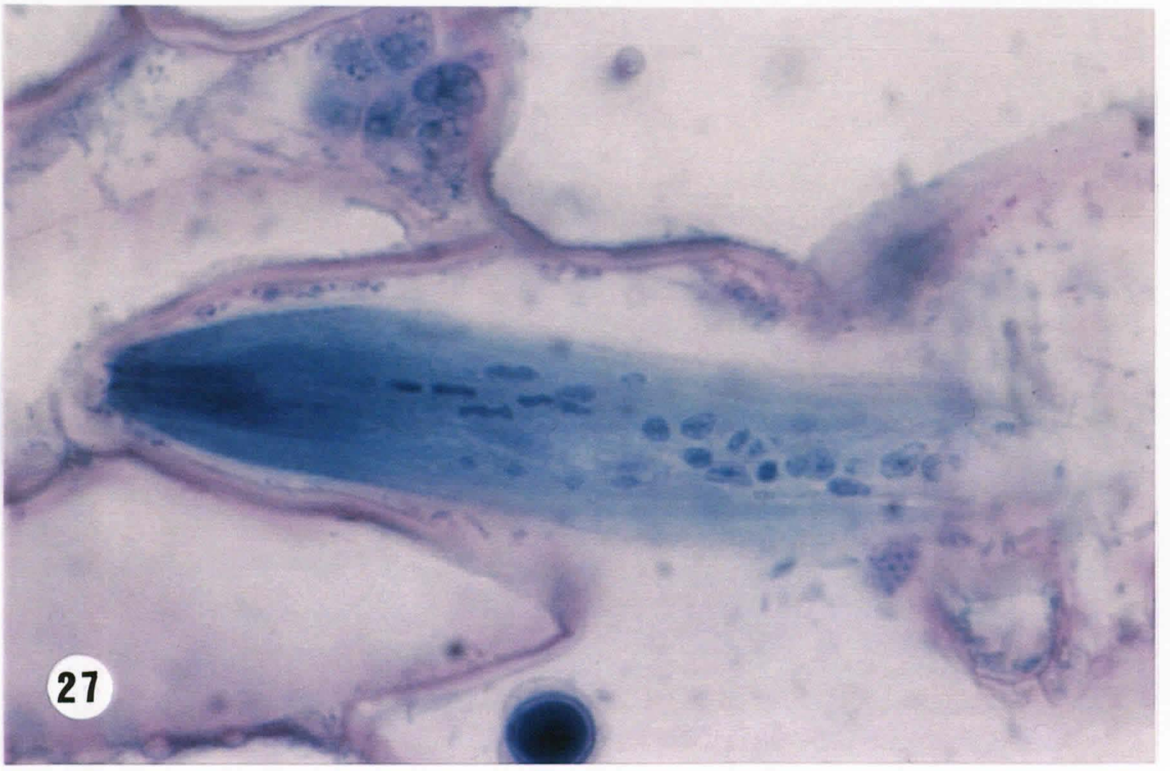
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LEGENDS

Photo 28. Simulation of a 10-year old coconut plantation in the RSUP conditions (PB 121) :

- attacks of *Sufetula* which reduce the length of the horizontal RI to 1.5 - 3 m long,
- water table at 1m depth.


28

LEGENDS

Photos 29 and 30.

Simulations of a 10-year old coconut plantation where the PB 121 coconuts are associated with pineapple.

29


30

CONCLUSIONS

CONCLUSIONS

The qualitative method of observing the root systems of PB 121 coconut palms in large holes at RSUP revealed that *Sufetula* attacks are at least partly responsible for the low yields of these hybrids. However, the quantitative method of estimating attacks by this pest on roots does not always enable a statistical link to be established between the number of nuts on the coconut palms and caterpillar attack rates. The drop in yields would appear to be more linked to a cumulated effect of the attacks, which is tricky to evaluate, since none of the coconut palms has a perfectly healthy root system.

Substantial heterogeneity has already been noted in the coconut palms at this plantation. It is reflected in the existence of very tall palms (over 7 m), average sized palms (5 to 6 m) and small palms (2 to 3 m). A good statistically positive relation has been shown between the height of the palms, the fresh root weight and the number of flowers + nuts on the palms. Such heterogeneity results from the interaction of different agronomic factors, including (Figure 1):

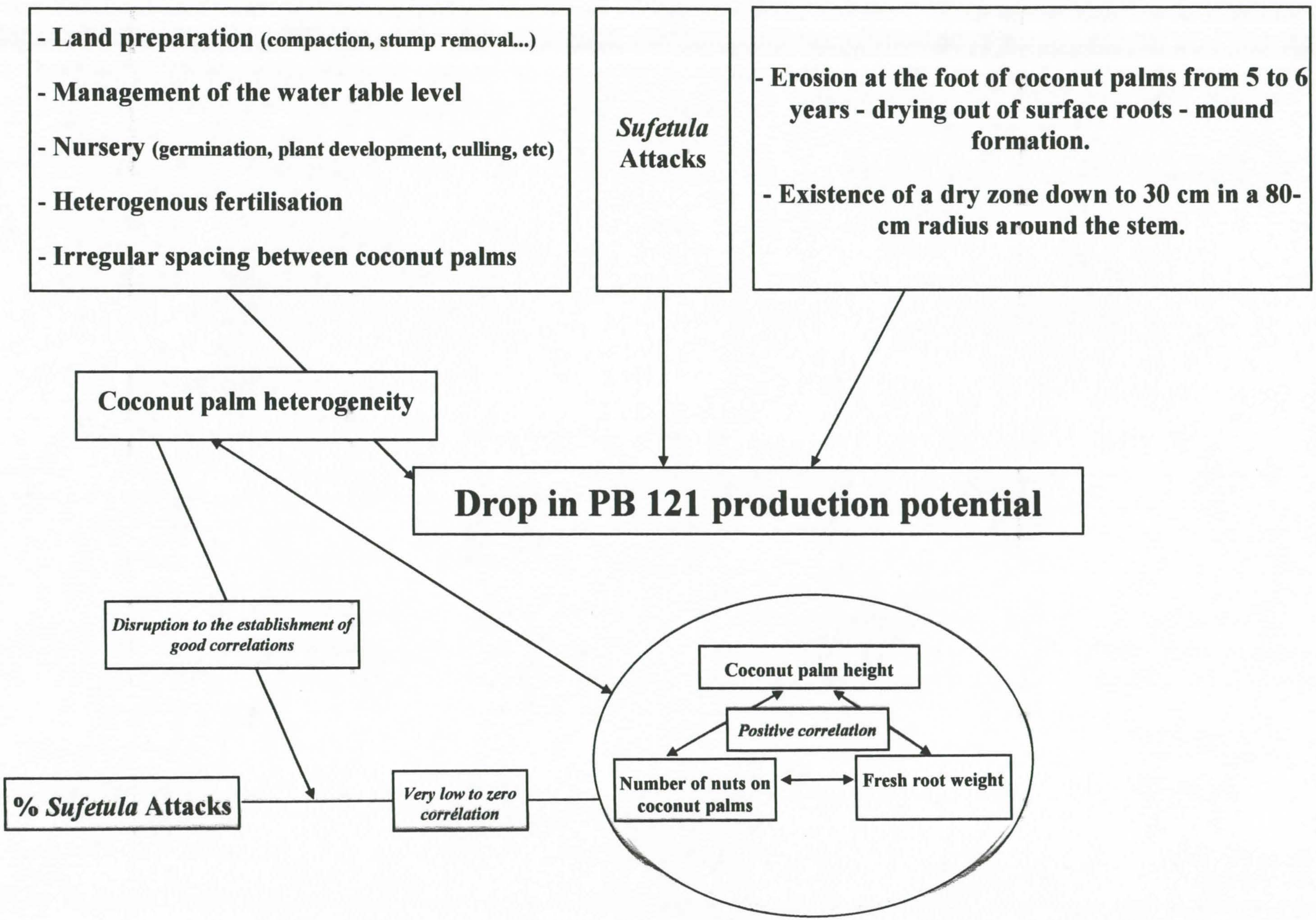
- **land preparation**: compaction prior to planting
- **water table management**: plant development is slowed down if the water is too near the surface (less than 40 cm down) a few months after planting.
- **nursery**: germination, root development and culling
- **fertilization**: fertilizers may be distributed very unevenly around a coconut palm or from one palm to the next.
- **spacing between the palms** is very inconsistent along the planting rows. The distance between the rows is not always the same.
- **soil erosion** uncovers the absorbent surface roots and causes mounds to form.

Attacks by this insect are never severe, sudden or localized in time and space. They are only slight in general and occur irregularly and on a continuous basis over the months and years. The generations overlap. However, the effects of the attacks on spatial limitation of the coconut root system are spectacular.

There are now three insecticides available (Larvin, Dursban and Supracide) that can slow down attacks by these caterpillars. The beneficial effects of treatments on yields are yet to be confirmed.

A new trial has been set up to define a practical way of protecting against *Sufetula* and erosion, whilst improving moisture levels in the upper horizons of the soil around the coconut palm stems.

Figure 1 : FACTORS LIMITING COCONUT YIELDS AT RSUP / PULAU BURUNG



RECOMMENDATIONS

RECOMMENDATIONS

HSF 07: Reproduction of *Sufetula* symptoms by root sectioning

Halt observations in this trial. A year of results has been obtained which do not show any significant differences between treatments. In the treatment with 100% sectioned roots, there was only a reduction of a single leaf. The difference in the number of nuts found on the palms was not very great from one treatment to another: barely 5 to 8%. Moreover, sectioning the lignified part of a root does not cause reiteration of a new root. Reiteration only occurs if the apex of a root is naturally destroyed or accidentally destroyed by an insect.

HSF 05: Effect of plastic sheets and treatments against *Sufetula* on yields

Continue with this trial in line with the norms defined in the protocol.

RS CC 07/02-04/RSTM: Effect of silica and treatments against *Sufetula* on yields

Use the same dose of 15 ml of Dursban 20EC per plant in 1.5 litres of solution per plant in a radius of 50 cm
Treat every month as there are no *Sufetula* attacks.
As soon as attacks begin in the control, treat every fortnight again with a dose of 30 ml of Dursban.

HSF 09 / K6-03: Monitoring *Sufetula* adult emergence

From now on, monitor every two weeks. The first results are interesting.
Count the nuts on the palms every three months, from L10 to the lowest leaf.
If the number of adults emerging is virtually zero, check every month.

HSF10 / A07-01: Testing of different insecticides

This trial has been modified as follows:

D1	15 ml Dursban/6 litres of water/coconut palm, every month
L2 (=D2)	12 ml Larvin/6 litres of water/coconut palm, every month
L	6 ml Larvin/6 litres of water/coconut palm, every month
SU2 (= DM)	20 ml Supracide/6 litres of water/coconut palm, every month
SU	10 ml Supracide/6 litres of water/coconut palm, every month
C	Control

NB: Add 1 ml of adhesive per litre of water to each treatment

HSF 11/A07-02: Effect of treatments against *Sufetula* on yields

D1	30 ml Dursban/6 litres of water/coconut palm, every month
D2	30 ml Dursban/3 litres of water/coconut palm, every month
C	Control

NB: Add 1 ml of adhesive per litre of water to each treatment

HSF 12: *Sufetula* rearing

Continue the rearing trials in quite deep, opaque white plastic dishes.

<u>HSF 13</u>: Light traps

Try different coloured light bulbs or bulbs giving different types of ultra violet rays.

Population dynamics:

At RSUP, keep the most worthwhile plots that are the most typical of *Sufetula* larva population trends.
Four plots, e.g. A6-03; A09-08; B11-09; K3-01; A12-03.
Root samples should be taken from two 1.00 m x 40 cm x 40 cm holes; 1 in the planting row, the other in the interrow 0.80 m from the stem.
Carefully totalize healthy roots, and especially any new attacks.

At RSTM, choose a plot of PB 121 aged 6 months to 1 year planted under the usual conditions, to monitor *Sufetula* attacks every three months.
Carry out a set of surveys in a few RSTM plots containing numerous hybrids, e.g.:
1 plot of CRD x WAT; NYD x PALU; NYD x PYT; CRD x RLT and MYD x WAT.

Use the small random draw program for sample taking.

<u>Miscellaneous</u>:

☞ Order three other insecticides to continue the search for effective molecules against *Sufetula*:

Diazinon, Endosulfan, and especially Oncol.

☞ Place *Sufetula* in the glass box as soon as the roots of transplanted nursery plants are visible against the pane.

☞ Change the pane of the rhizotron positioned at the foot of coconut palm 50-04 in plot A07-02.

☞ New trial: At RSUP check the following young plots (2 to 3 years old): 05-00 (April 95); 04-00 (February 95); 03-00 (December 94); 02-00 (December 94). If there are any *Sufetula* attacks in those plots, it would be interesting to set up a trial to protect them from the insect with the following treatments:

- Bare soil
- Bare soil + cocopeat or dried leaves in 1.5-m radius around the stem
- Bare soil + cocopeat or dried leaves in a 1.5-m radius around the stem + insecticide treatment every three months
- Normal plant cover + clean circle
- Normal plant cover + cocopeat or dried leaves in a 1.5-m radius around the stem
- Normal plant cover + cocopeat or dried leaves in a 1.5-m radius around the stem + insecticide treatment every three months
- Insecticide + adhesive once a year
- Insecticide + adhesive twice a year
- Insecticide + adhesive 4 times a year.

Elementary plot: 5 rows x 5 coconut palms - 3 replicates per treatment.